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LEROY KEENE CLARK

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**DRINKING INDUCED BY SECOND-ORDER FOOD SCHEDULES:  
MULTIPLE CONTROLLING FACTORS**

*University of New Hampshire*

**PH.D. 1981**

**University  
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DRINKING INDUCED BY SECOND-ORDER FOOD SCHEDULES:  
MULTIPLE CONTROLLING FACTORS

BY

LEROY K. CLARK

B.A. (Psychology), University of Southern Maine, 1975

M.A. (Psychology), University of New Hampshire, 1978

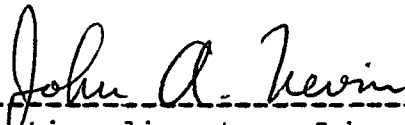
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the Requirements for the Degree of

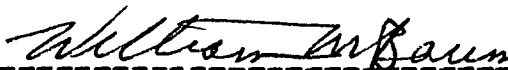
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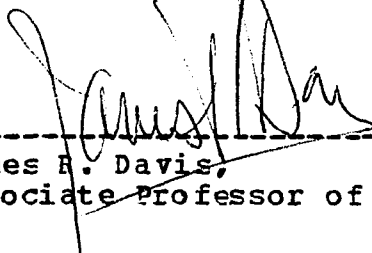
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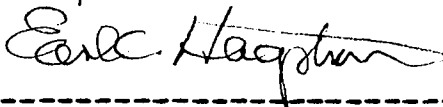
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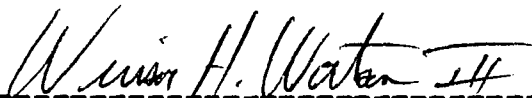
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-----  
James R. Davis,  
Associate Professor of Psychology



-----  
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-----  
Winsor H. Watson,  
Assistant Professor of Zoology



-----  
Perrin S. Cohen,  
Associate Professor of Psychology,  
Northeastern University



-----  
Date

## DEDICATION

To my loving wife, Gail, without whose understanding, encouragement, assistance, and occasional prod the writing of this dissertation might still be a project for tomorrow.

and

To the memory of my father who was always there during my 24 years of schooling, but who wasn't permitted to see their conclusion.

## ACKNOWLEDGEMENTS

All phases of the research were supported by NSF Grant #BNS 79-24082 awarded to the University of New Hampshire, J. A. Nevin, principal investigator. Preliminary research, Experiment 1, and Experiment 3a were partially funded by Central University Research Fund Grant #SS137 awarded by the University of New Hampshire in 1979. Funding made available through the Research Office of the University of New Hampshire made possible the use of the UNH DEC-10 computer facilities for the analysis and plotting of data and for the preparation of this manuscript. Statistical analyses made use of the Minitab program as implemented at UNH.

I would like to thank Tony Nevin for his consistent encouragement and numerous suggestions which helped in imposing some sort of order on a mountain of data. He is not, however, responsible for any inaccuracies contained herein-- I take full responsibility for those.

Finally, and most important, I would like to thank my family for their support and for their understanding of my protracted absences from home while my research and the preparation of this dissertation were in progress. Both certainly made my job easier.

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ABSTRACT

DRINKING INDUCED BY SECOND-ORDER FOOD SCHEDULES:  
MULTIPLE CONTROLLING FACTORS

by

LEROY K. CLARK

University of New Hampshire, December, 1981

Excessive drinking is one of a number of behaviors induced by periodic food presentations. Second-order schedules have been used to differentiate between physiological (eating-related) and psychological (schedule-related) factors which might contribute to induced drinking. In second-order schedules, some of the food presentations are replaced by brief stimulus presentations. The occurrence of post-stimulus drinking is regarded as reflecting the influence of psychological factors.

Preliminary research agreed with published accounts in that post-stimulus drinking by rats was typically less reliable and less robust than post-food drinking. Animals that drank most reliably during post-stimulus components tended to resume drinking following the onset of lever-pressing during post-food components. Such drinking, like post-stimulus drinking, consisted of short bouts which

alternated with bouts of lever-pressing. It was hypothesized that short-bout licking might be a terminal activity, a behavior whose rate of occurrence varies directly with the probability of food presentations.

In Experiment 1, a contingency which required that licking occur during each component of a second-order schedule led to an increase in the rate of occurrence, but not in the durations, of short lick bouts.

In Experiment 2, auditory signals informed animals, throughout each component, of the outcome (food or stimulus presentation) to follow that component. A clear discrimination in lever-pressing between pre-food and pre-stimulus signals was observed. Signal effects on drinking were minimal, indicating that short-bout drinking is not a terminal activity.

Control animals not given outcome-signals did not reliably engage in short-bout drinking, while 8 of 9 animals presented with such signals did. Short-bout drinking declined following removal of the signal-outcome correlation. Environmental predictability may influence short-bout drinking.

In Experiment 3, drinking after a food-paired stimulus on probe trials differed from that observed following presentations of a stimulus not paired with food. Drinking following the food-paired stimulus more closely resembled

post-food drinking in bout duration, latency, and number and distribution of licks within components.

Short-bout drinking is not a terminal activity, and is independent both of the rate and of the occurrence of lever-pressing. While short-bout drinking is sensitive to reinforcement contingencies, it is not normally so controlled. The drinking style commonly described as schedule-induced depends upon the prior presentation of food or of a food-correlated stimulus.

## I. INTRODUCTION AND LITERATURE REVIEW

It has become clear in recent years that the periodic presentation of food to hungry animals may give rise to distinctive patterns of behavior. Staddon and Simmelhag (1971) presented hungry pigeons with food according to a schedule which delivered food at 12-sec intervals independently of the animals' behavior (Fixed Time [FT] 12-sec schedule). Behavior that occurred early in the interreinforcement interval (post-food behavior, interim activities) differed consistently from behavior that occurred later in the interval (pre-food behavior, terminal activities). Interim behavior included wing-flapping and orientation away from the feeder area. Terminal behavior included pecking and orientation toward the feeder area. The pattern of behavior during interreinforcement intervals frequently assumed a stereotyped character, the nature of which varied among birds. A similar distinction between interim and terminal was made with respect to the behavior of rats presented with food according to a FT 30-sec schedule (Staddon and Ayres, 1975). The rats' interim behavior included drinking and running. Terminal behavior consisted largely of nosing around the feeder.

With both rats and pigeons, the probabilities of interim and terminal behavior followed distinctive time courses during the interreinforcement interval. The probability of interim behavior peaked early in the interval and declined thereafter. The probability of terminal behavior was low soon after food deliveries, but increased throughout the interval. Terminal behavior, once begun, typically occupied the remainder of the interreinforcement interval (Staddon, 1977). Similar results have been found with response-dependent schedules in which reinforcement is contingent upon the occurrence of a specified response. The required response may be regarded as the principal form of terminal behavior in response-dependent schedules.

While terminal behavior, in the form of required responding, has been extensively studied for at least 42 years (Skinner, 1938), it is only in the last 20 years that researchers have begun systematic investigations of interim behavior. Contemporary interest in interim behavior developed as a consequence of research by Falk during the 1960's. Falk (1961) required that rats press a lever for food, small amounts of which became available every 60 sec [Fixed Interval [FI] 60-sec schedule). Unlike most earlier investigators, Falk made water freely available to his rats during the experimental sessions. Falk found that under these conditions rats would ingest abnormally large quantities of water. Session intakes of water were often as high as 100 ml (nearly half the animals' body weights), some

2.5 - 4 times the normal 24-hr intake of such rats (Falk, 1961). This copious intake of water occurred during sessions which lasted slightly longer than three hours.

A series of studies by Falk and others (reviewed by Falk, 1969, 1971) provided no physiological explanation for the excessive drinking. The drinking did, however, appear sensitive to the parameters of the reinforcement schedule, particularly the duration of the interreinforcement interval. Drinking levels were bitonically related to interval duration, increasing to a maximum at interval durations of 2 - 4 min., and decreasing thereafter. Further, the excessive drinking disappeared when periodic food presentations were discontinued. For these reasons, the excessive drinking was described as schedule-induced polydipsia, or schedule-induced drinking.

Falk (1969, 1971) pointed out similarities between the various types of interim or schedule-induced behaviors and the behaviors which occur as displacement activities in natural settings. Among the interim activities which have been investigated are running (Levitsky and Collier, 1968), ingestion of nondigestible substances (Freed and Hymowitz, 1969), licking at air streams (Taylor and Lester, 1969), aggression against conspecifics (Huston and DeSisto, 1971), and general motor activity (Kelly and Hake, 1970; Osborne, 1978). Species in which interim behavior has been studied include pigeons (Magyar and Malaqodi, 1980; Shanab and Peterson, 1968; Staddon and Simmelhag, 1971), doves



{McFarland, 1965), monkeys {Allen and Kenshalo, 1976), mice {Palfai, Kutscher, and Symons, 1971), guinea pigs {Porter, Sozer, and Mceschl, 1977), gerbils {Porter and Bryant, 1978), and humans {Kachanoff, et al., 1973; Kelly and Hake, 1970), as well as rats.

Apart from its apparent wide generality, interim behavior is worthy of further study for at least two reasons.

Firstly, these behaviors often occur in excess-- far above levels observed in the absence of periodic food presentations. The excessive character of interim drinking has already been described. Interim aggression in pigeons is sufficiently intense that investigators often use stuffed decoys in place of live targets. Further, interim behavior may occur even when it has the effect of delaying food presentations {Flory and Lickfett, 1974). The excessive character of schedule-induced behaviors, together with their stereotypy and reliable occurrence, have led a number of investigators (e.g., Cantor and Wilson, 1978; Falk, 1977) to suggest that this type of behavior might serve as a model for human compulsive behavior. Whether or not the perceived analogy between compulsive and interim behavior is valid, it would clearly be useful to understand how such apparently maladaptive behavior arises and how it may be controlled.

Secondly, an understanding of schedule-induced behavior may shed light upon the mechanisms by which motivational systems interact. Schedule-induced aggression in pigeons

resembles "natural" aggression with respect to the features of the target by which it is controlled (Looney and Cohen, 1974) and with respect to the character of concurrently emitted vocalizations (Rashotte, et al., 1975). Schedule-induced drinking resembles deprivation-induced drinking in that both are attenuated by stomach preloading with water (Cope, Sanger, and Blackman, 1977) and by systemic injections of atropine (Burks and Fisher, 1970), and both are sensitive to the palatability of the liquid which is ingested (Falk, 1966; Segal and Deadwyler, 1965; Wayner and Greenberg, 1972). Yet the occurrence of schedule-induced behavior depends upon such parameters of the food presentation schedule as frequency and magnitude of reinforcement (Falk, 1971), suggesting that factors which might intuitively be thought to control activity within the motivational system responsible for eating are capable of influencing activity within other motivational systems.

Drinking by rats has been the most widely studied of the various interim behaviors. The research emphasis on interim drinking has been unfortunate from a theoretical perspective because there is evidence to suggest a special relationship between drinking and eating in rats. Kissileff (1969) found that when both food and water were freely available to non-deprived rats, some 40% of the animals' daily water intake occurred during periods immediately following eating. Fitzsimons and LeMagnen (1969) showed that the amount of drinking which occurs after a meal is a

direct linear function of meal size. The association between eating and drinking extends also to the case of hungry rats which, when allowed free access to both food and water, alternate between bouts of eating and drinking (Lotter, Woods, and Vasselli, 1973).

It has been argued (Lotter, Vasselli, and Woods, 1973; Stein, 1964) that the drinking which occurs between periodic food presentations is nothing more than a manifestation of the rat's natural inclination to drink upon completion of a meal. Each food presentation may be regarded as the equivalent of a small meal. The large water intake seen during experimental sessions is then a consequence of the animal's drinking after each of a relatively large number of meals during the session. If this view were correct, it would diminish the usefulness and generality of schedule-induced drinking as a model interim behavior.

Evidence to support the view that schedule-induced drinking is best regarded as a purely post-prandial phenomenon is as follows. First, most interim drinking occurs during periods which immediately follow consumption of the food reinforcer (King and Schaeffer, 1973; Schaeffer and Salzberg, 1973). Second, the amount of drinking per interreinforcement interval is a function of reinforcer magnitude (Couch, 1974; Falk, 1967; Flory, 1971). Third, drinking fails to develop if Wesson oil is used as a reinforcer in place of food (Stricker and Adair, 1964), and, once developed, drinking may disappear if food reinforcers

are replaced either by milk (Stein, 1964) or by intracranial stimulation (Cohen and Mendelson, 1974). Finally, use of food containing a high percentage by weight of water may retard the development of schedule-induced drinking (Hawkins, et al., 1972).

The interpretation of interim drinking as solely an automatic response to food ingestion has not been universally accepted. Both Wayner (1974) and Killeen (1975) have argued that food presentations to hungry animals may be regarded as stimuli which elicit a transient increase in nonspecific arousal. In this view, arousal, which is regarded as an energizer of behavior, augments the already-present behavioral tendencies of the animal. High levels of drinking are maintained by periodic food presentations because the animal's tendency to drink after eating is elevated by the arousing effect of the food presentations.

Behavior at any point in time is a joint function of the animal's internal state, including level of arousal, and of the features of its environment. If water is unavailable, other behaviors take the place of drinking. Like drinking, these behaviors occur at higher levels than would be observed in the absence of periodic food presentations because of the energizing effect of such events.

Partial support for this view comes from Killeen's (1975) research which indicates increased motor activity immediately following reinforcement. Osborne (1978) showed that, as with schedule-induced drinking, the extent of the post-reinforcement increase in general motor activity is a function of reinforcer magnitude. Thus the effect of reinforcer magnitude on interim drinking cannot be regarded as demonstrating that such drinking occurs solely as a response to the consequences of food ingestion.

The above fails to explain why behaviors other than the required response should be energized by food presentations. Staddon (1977) has argued that when food is presented at regular intervals, the early (post-food) and late (pre-food) portions of interreinforcement periods acquire the properties of discriminative stimuli. The post-food period acts as a signal that the probability of food's being presented is temporarily low, while the pre-food period signals that the probability of a food presentation is high.

While the probability of reinforcement is low during the post-food period, the motivational state of the animal is different from that which prevails during periods of high reinforcement probability. Staddon (1977) referred to the animal's motivational state early in the interreinforcement interval as an interim state; the motivational state late in the interval was referred to as a terminal state. Within this framework, behavioral tendencies controlled by the interim state would be augmented by the arousing effect of

food presentations, and might, therefore, give rise to excessive behavior.

The character of the interim state depends both upon the types of environmental stimuli present and upon the types of behavior in which the animal is likely to engage. If water is present and if the reinforcer is food, then the interim state is likely to resemble thirst, at least in rats. Falk (1966) and Allen and Porter (1975) found that rats would perform a response in order to gain access to water during the post-food period, exactly as would be expected if the animals were thirsty. Staddon (1977) reported that once animals had received sufficient training to establish the discriminative functions of the post- and pre-food periods, they often failed to eat food presented unexpectedly during the post-food period. It seems, therefore, that although food-deprived rather than water-deprived, animals might drink during the post-food period because they are thirsty rather than hungry.

Evidence to support Staddon's (1977) contention that interim behavior depends upon discriminable periods of low and high reinforcement probability comes from research in which drinking during exposure to Random Interval (RI) schedules is compared to drinking during exposure to Variable Interval (VI) schedules of food presentation. RI schedules are so designed that the probability of reinforcement is held at a uniformly low level throughout the experimental session. Thus reinforcement is

equiprobable at all times. VI schedules, by comparison, are comprised of a relatively small number of pre-specified interreinforcement interval durations. With such schedules, there are periods when food may become available with some probability and other times at which food never becomes available.

Millerscn, Allen, and Pinker (1977) obtained reliable interim drinking from only two of eight rats exposed to a RI 60-sec schedule, while all four rats exposed to a VI 60-sec schedule exhibited appreciable interim drinking. This finding was replicated by Lashley and Rossellini (1980) with rats exposed to a RT 120-sec schedule. In a second condition, Lashley and Rossellini (1980) found that when food presentations on the RT 120-sec schedule were preceded by a 5-sec warning stimulus, thereby separating the session into discriminable periods of high and low reinforcement probability, rats exhibited appreciable interim drinking.

In summary, there is evidence that interim drinking may be partially a consequence of factors related to an animal's natural tendency to drink after eating and partially a consequence of other factors related to an animal's experience with the food presentation schedule. The sorts of experiments thus far described do not successfully isolate the relative contributions of these factors because periods of low reinforcement probability and presumably of high arousal, which may respectively give rise to and enhance interim drinking, closely follow the consumption of

food, thereby confounding the two types of factors. This problem may be circumvented through the use of second-order reinforcement schedules.

In second-order schedules, some proportion of the food presentations is replaced by presentations of another stimulus such as a light flash or a brief tone. The stimulus presentation is equivalent to the food presentation with respect to information content. Each signals the start of a period of low reinforcement probability.

The experimental session may be regarded as composed of two types of intervals or components-- those which begin with food presentations (post-food components) and those which begin with stimulus presentations (post-stimulus components). Comparisons can be made between behavior during post-food components and behavior during post-stimulus components. For the present purposes, the question of interest is whether drinking will occur during post-stimulus components as well as during post-food components. The occurrence of drinking during post-stimulus components would be powerful evidence that interim drinking is controlled by reinforcement probability (Staddon, 1977) as well as by the prior ingestion of food (Lotter, Woods, and Vasselli, 1973, Stein, 1964).

Kelleher (1966) has described a notational system for the description of second-order schedules. If every third completion of a Fixed Interval (FI) 60-sec component ends with a food presentation, then the schedule may be described



as a Fixed Ratio (FR) 3 (FI 60:S) second-order schedule. If, on average, every other FI 60 component ends with a food presentation, the schedule may be described as Variable Ratio (VR) 2 (FI 60:S). The ":S" serves to indicate that a stimulus is presented when food deliveries are omitted. If the stimulus is one which also accompanies food deliveries (paired stimulus), then an appropriate notation might be VR 2 (FI 60:Sp). If the stimulus never occurs in conjunction with food presentations (non-paired stimulus), then an appropriate notation might be VR 2 (FI 60:Sn) (Stubbs, 1971).

Rosenblith (1970) studied interim drinking by rats exposed to a FR 3 (FI 60:Sp) second-order schedule. Food deliveries, occurring upon completion of every third component, were accompanied by a click and preceded by a 2-sec flash of an overhead light. Stimulus presentations occurring in place of food deliveries consisted of the light flash followed by the click.

In Rosenblith's (1970) experiment, drinking initially occurred only following food presentations. After several weeks of training, however, drinking also began to occur during post-stimulus components. Post-stimulus drinking, once acquired, consisted of a burst of licking immediately after the stimulus presentation, followed by alternating bursts of licking and responding. Asymptotic levels of post-stimulus drinking were lower than those for post-food drinking. An increase in the size of the reinforcer from 45

to 250 mg led to an increase in the level of post-stimulus drinking for all three subjects. The level of post-food drinking increased for only one of the three subjects when the reinforcer magnitude was increased. The effects of reinforcer magnitude on drinking were later replicated by Allen and Porter (1977).

Corfield-Sumner, Blackman, and Stainer (1977) exposed one group of rats to a VR 2 (FI 60:Sn) response-dependent schedule. A second group of rats was exposed to a VR 2 (FT 60:Sn) response-independent schedule. Food presentations consisted of the sequential delivery of four 45-mg pellets at 0.5-sec intervals. The stimulus presented in place of food deliveries consisted of a 1.5-sec burst of white noise from an overhead speaker, accompanied by extinction of the houselight. The sequence of food and stimulus presentations was random.

As in Rosenblith's (1970) study, post-stimulus drinking was acquired more slowly and reached a lower asymptote than did post-food drinking, at least among rats in the response-dependent condition. Rats in the response-independent condition failed to exhibit appreciable post-stimulus drinking. Cumulative records suggested that post-stimulus lick bouts tended to be much shorter than post-food lick bouts. Frequently several short lick bouts occurred during post-stimulus components whereas post-food drinking typically consisted of a single long bout of licking.

Clark (1978, unpublished) observed appreciable post-stimulus drinking when rats were exposed to a VR 2 (FI 60:Sn) schedule. The nonpaired stimulus consisted of a 1.5-sec tone presentation. Reinforcers consisted of the presentation, at 1.5-sec intervals, of 1 - 7 45-mg food pellets. As with the previous studies, post-stimulus drinking developed more slowly and reached a lower asymptote than did post-food drinking for three of the four rats. For the fourth rat, post-food and post-stimulus drinking developed in parallel and reached similar asymptotic levels. Drinking occurred primarily during the first 40 sec of post-food components, but was evenly distributed throughout post-stimulus components. Post-stimulus drinking was characterized by a somewhat longer latency than was post-food drinking. Finally, bouts of licking during post-stimulus components tended to alternate with bouts of responding whereas post-food drinking was seldom interrupted by responding.

Other investigators have had difficulty in obtaining reliable post-stimulus drinking from rats exposed to second-order reinforcement schedules (Allen, Porter, and Arazie, 1975; Allen and Porter, 1977; Clark, 1978, unpublished; Porter, et al., 1975). The reasons for these failures remain to be discovered.

Of more immediate concern are the reported differences between post-food and post-stimulus drinking. These differences include the lower levels of post-stimulus

drinking, the slower acquisition of post-stimulus drinking, the alternation during post-stimulus components between licking and responding, the difference in latency, the difference in lick distributions, and the difference in sensitivity to increases in reinforcement magnitude. If second-order schedules give rise to drinking which differs qualitatively from post-food drinking, then the usefulness of these schedules to investigations of interim behavior may be diminished. No studies to date have addressed this issue.

The objectives of this dissertation were twofold. The first was to determine whether post-food and post-stimulus drinking should be regarded as qualitatively different behaviors. The second, assuming there are qualitative differences between the two, was to attempt to categorize post-stimulus drinking within the interim-terminal framework.

## II. PRELIMINARY RESEARCH

It is the purpose of this section to summarize observations made on a relatively large number of subjects during preliminary research with VR 2 (FI:Sn) second-order schedules. This will provide both a point of departure for the experimental manipulations described in later sections, and a background against which to assess the effects of those manipulations.

A total of 21 subjects were studied: 13 (301 - 306, 701 - 707) albino (CD-- Charles River) and 8 Harvard Brown (Dr. William Baum, Psychology Dept., UNH) rats. All were approximately three months of age at the start of experimentation, and were maintained at 80% of their free-feeding weights while research was conducted. The methodology used was similar to that described under General Methods, except that the second-order schedule to which subjects 301 - 306 were exposed was comprised of 80-sec, rather than of 70-sec, components.

Figures 1 - 6 are intended to convey a general picture of behavior during exposure to second-order schedules. The data plotted in these figures depict the behavior of 4 subjects - 303, 506, 507, and 702 - which were subjectively judged to be the most reliable post-stimulus drinkers among

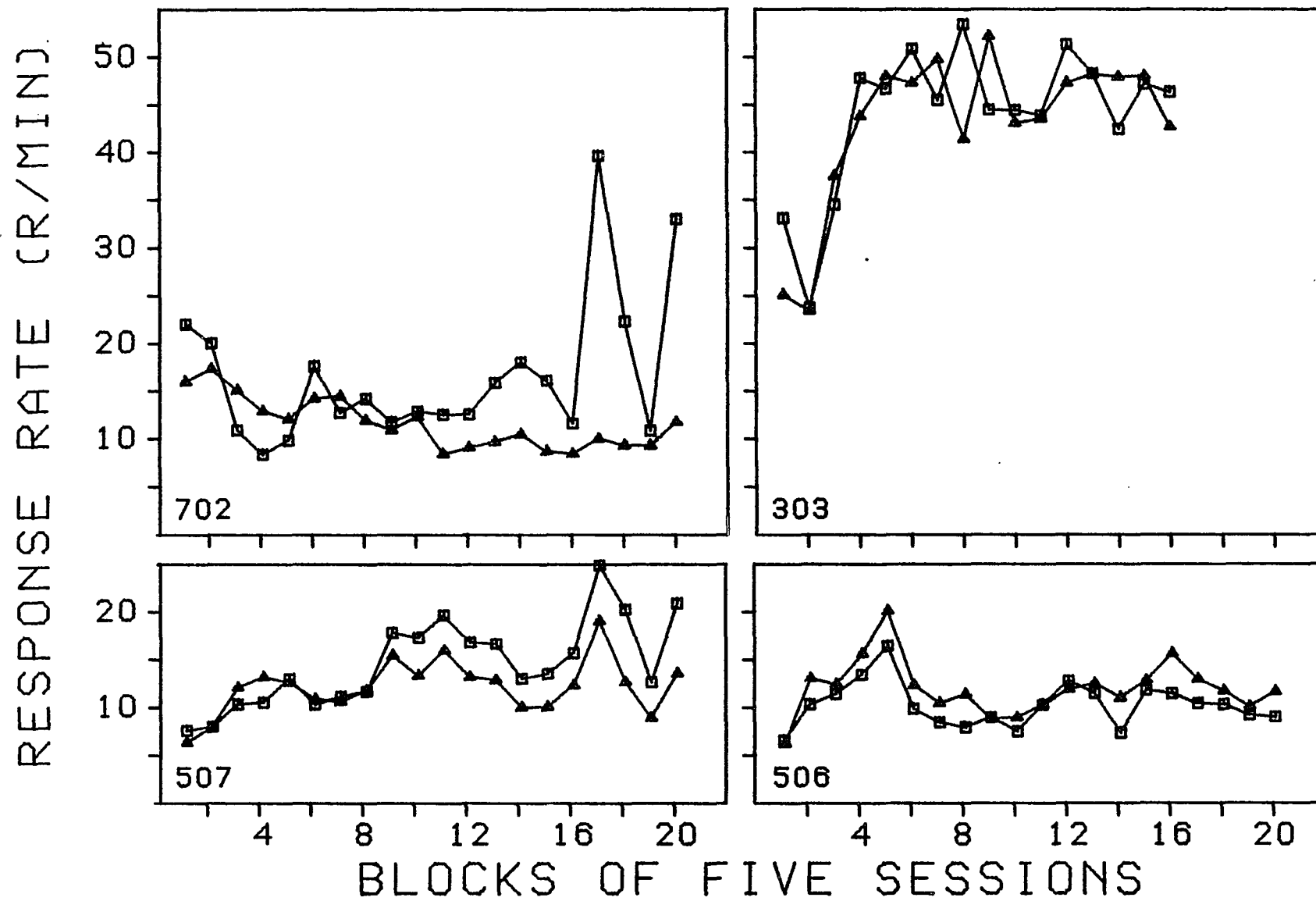
the rats studied. These subjects represent the full range of animal strains and training conditions studied. The data represent performance during the first 100 sessions of training, excluding special experimental manipulations (i.e., extinction, pre-feeding). Each point plotted represents mean performance over five consecutive sessions.

Figure 1 compares lever-press rates during post-food and post-stimulus components. These data, which represent running rates (latency subtracted from time base), demonstrate that there were no consistent between-subjects differences between post-food and post-stimulus lever-press rates. It was not at all uncommon, however, to find consistent within-subjects differences-- some subjects responded at a slightly higher rate during post-food components, others, during post-stimulus components. The general similarity of response rates during the two types of components resulted from combinations of few lever-presses (2 - 6) with long latencies (50 - 80 sec) during post-food components, and many lever-presses (15 - 60) with short latencies (3 - 10 sec) during post-stimulus components.

Figures 2 and 3 illustrate the manner in which lever-presses were distributed within components. Figure 2 shows that, during post-food components, most lever-presses tended to occur relatively late, during the second half of such components. The lever-press patterns shown in Figure 2 resemble those obtained by Kirk and Schaeffer (1973), and are characteristic of terminal behavior as described by

Response Rates

Figure 1. lever-press rates of four subjects (303, 506, 507, 702) during exposure to second-order schedules (80-sec components for Subject 303; 70-sec components for the others). Subjects 303 and 702 were albino; 506 and 507, Harvard Brown. Squares represent post-food rates; triangles, post-stimulus rates. Two subjects received pre-training with the component schedule (303 - 12 sessions; 702 - 15 sessions). Each point plotted represents performance averaged over five consecutive sessions.

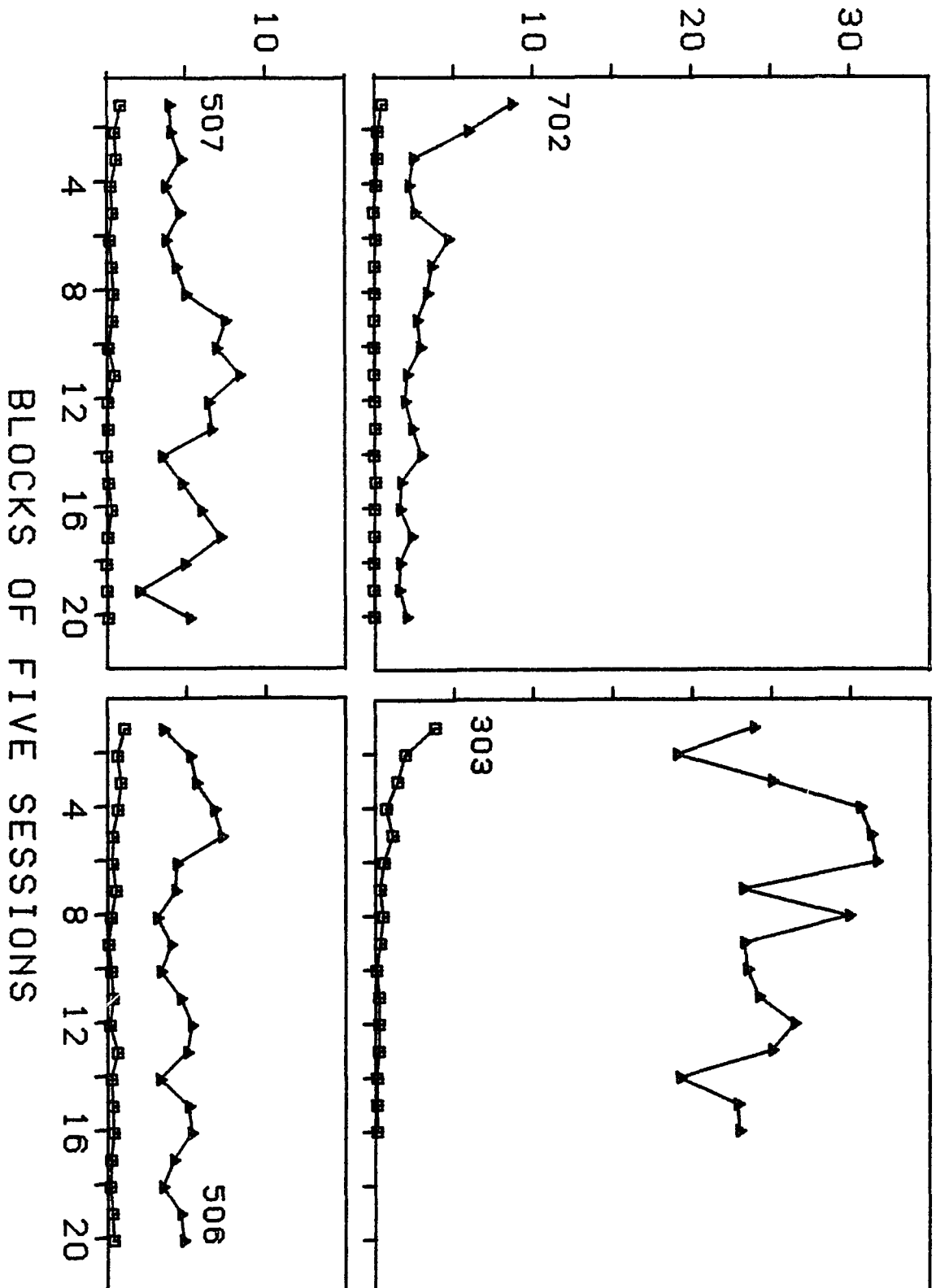




Post-Food Lever-Press Distributions

Figure 2. Post-food lever-press distributions for Subjects 303, 506, 507, and 702. Squares represent mean number of responses during the first half of each component. Triangles represent mean number of responses during the second half of each component. Each data point represents performance averaged over five consecutive sessions.

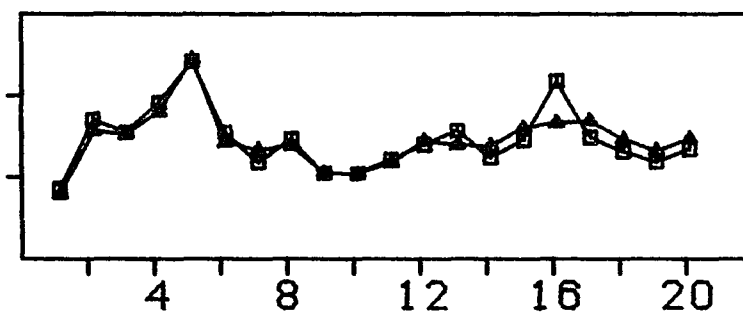
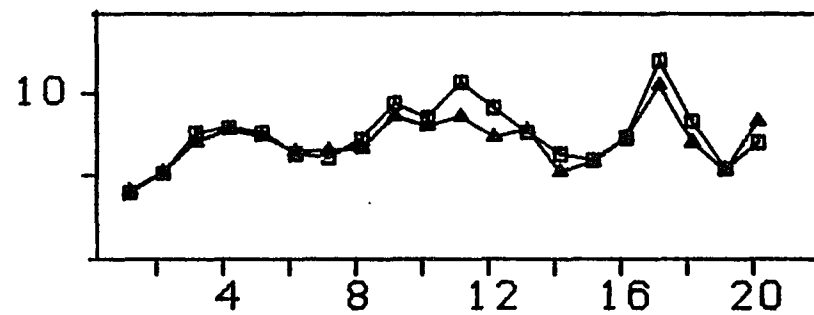
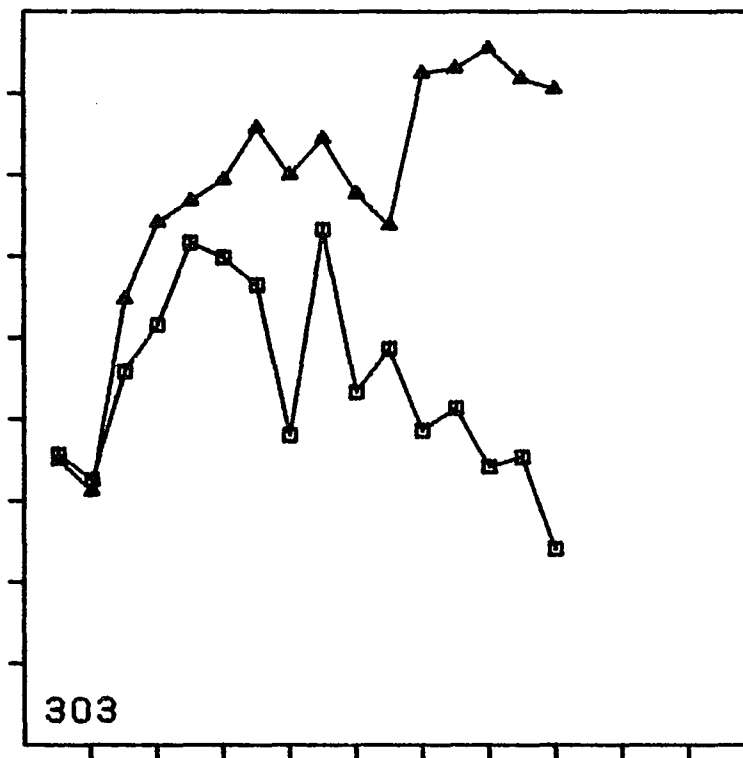
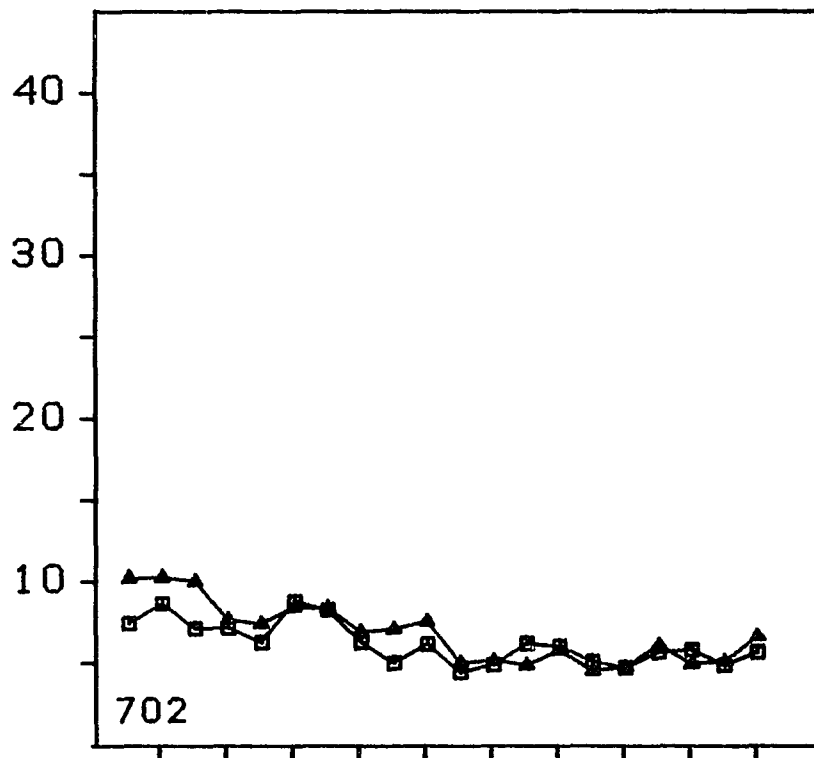
# NUMBER OF POST-FOOD RESPONSES



Post-Stimulus Lever-Press Distributions

Figure 3. Post-stimulus lever-press distributions for Subjects 303, 506, 507, and 702. Squares represent mean number of responses during the first half of each component. Triangles represent mean number of responses during the second half of each component. Each point plotted represents performance averaged over five consecutive sessions.

NUMBER OF POST-STIMULUS RESPONSES



BLOCKS OF FIVE SESSIONS

Staddon (1977). By comparison, Figure 3 shows that lever-presses tended to be evenly distributed throughout post-stimulus components for most subjects. Subject 303 was the single exception to this generalization. The failure of post-stimulus lever-pressing to assume the temporal pattern characteristic of terminal behavior suggests that stimulus presentations are, in most cases, less influential than food presentations as organizers of behavior.

With respect to drinking, it may first be noted that, after 30 sessions, approximately half (10 of 21) of the subjects studied drank reliably during at least 50% of post-stimulus components. Among the remaining subjects, drinking seldom occurred in more than 15% of post-stimulus components, and often occurred during less than 5% of such components. Eighteen of the 21 subjects (86%) reliably drank during at least 95% of post-food components after 30 sessions of training. The remaining 3 subjects reliably drank during at least 70% of such components. It may, therefore, be concluded that post-food drinking was, overall, a much more reliable phenomenon than was post-stimulus drinking. Among those rats which did drink reliably during post-stimulus components, however, it was quite common for the incidence (% of components with drinking) of post-stimulus drinking to approximate that of post-food drinking.

Upon initial exposure to the second-order schedule, the incidence of drinking ranged from 10 - 70% for both post-food and post-stimulus components. The incidence of post-stimulus drinking thereafter increased steadily among some subjects, and decreased among others, usually reaching an asymptote within 20 - 25 sessions. The incidence of post-food drinking increased steadily for all subjects following initial exposure to the second-order schedule, generally reaching an asymptote within 15 sessions.

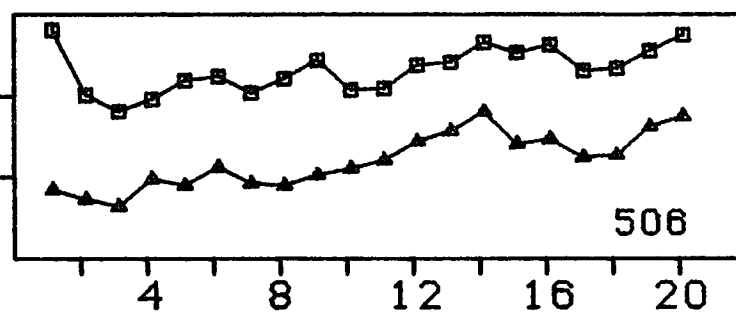
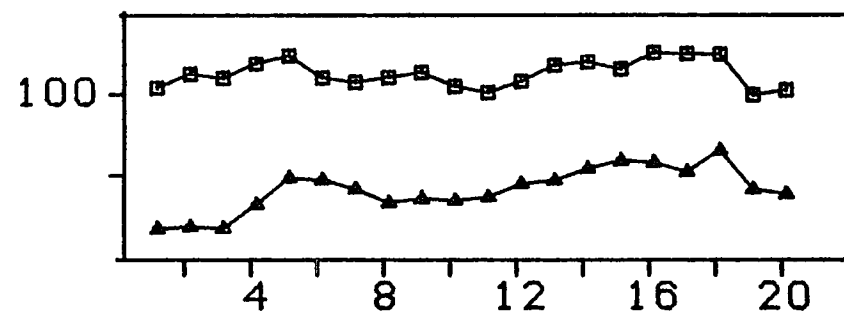
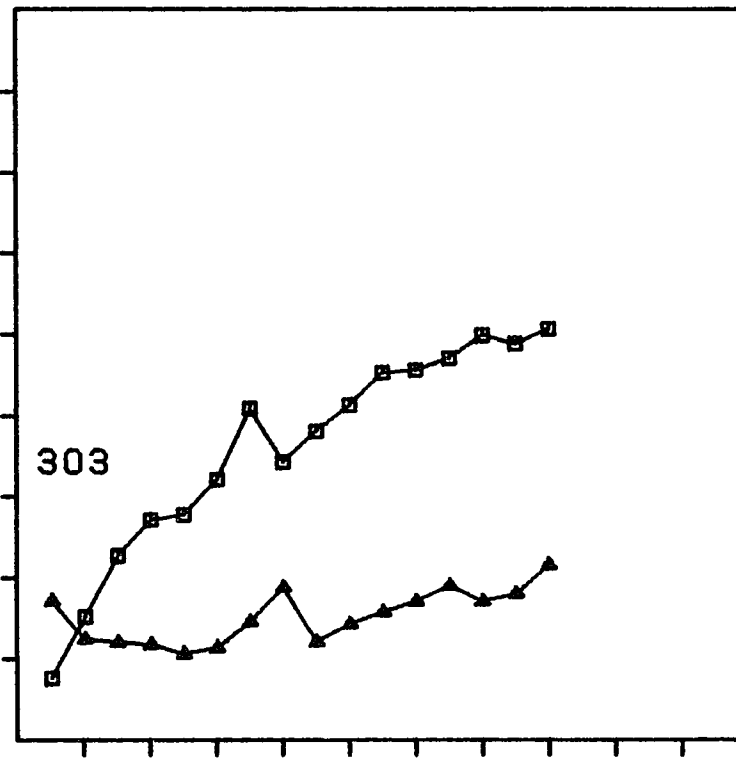
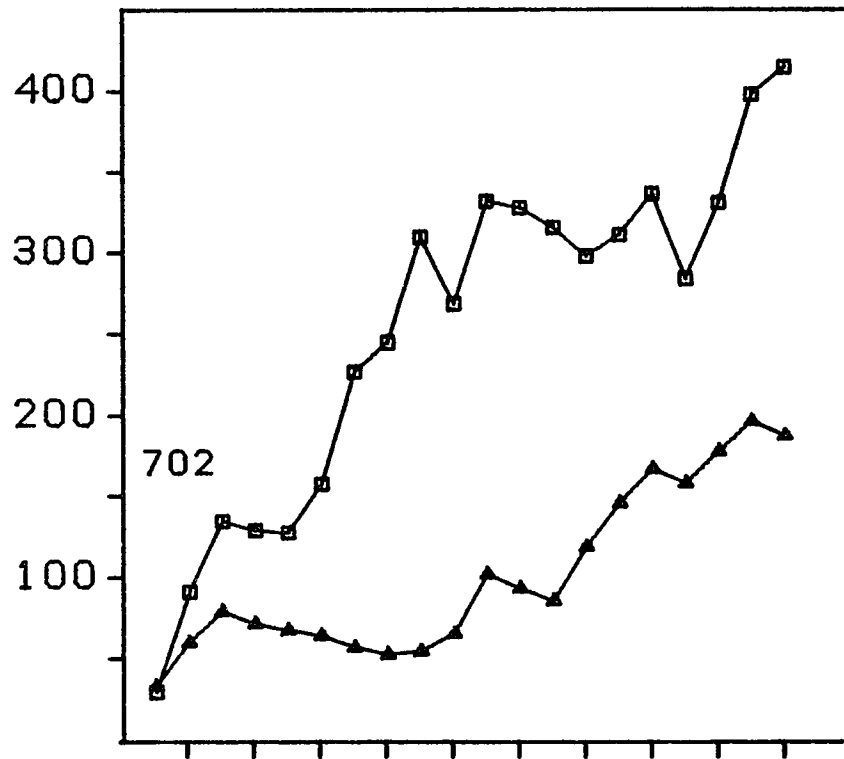
There were two exceptions to the preceding generalizations. The incidence of post-stimulus drinking reached an asymptote only after 45 sessions of training for one subject (702). A similar slow acquisition of post-stimulus drinking had also been observed by Clark (1978, unpublished). In only a single case did the incidence of post-stimulus drinking, once high, decline appreciably within a short period of time (10 - 15 sessions). That subject (305) exhibited a slow, steady increase during the first 50 sessions of training (to 85%), followed by a precipitous drop (to 10 - 15%) during the ensuing 10 - 12 sessions. The rarity of such occurrences will be important in the context of Experiment 2.

Levels (number of licks per component) of post-food and post-stimulus drinking are compared in Figure 4. The level of post-food drinking was typically higher than that of post-stimulus drinking. Two additional points deserve comment here. First, levels of drinking may not reach

Drinking levels

Figure 4. Mean number of licks per component during which drinking occurred for Subjects 303, 506, 507, and 702. Squares represent post-food drinking; triangles, post-stimulus drinking. Each point plotted represents performance averaged over five consecutive sessions.

NUMBER OF LICKS



BLOCKS OF FIVE SESSIONS

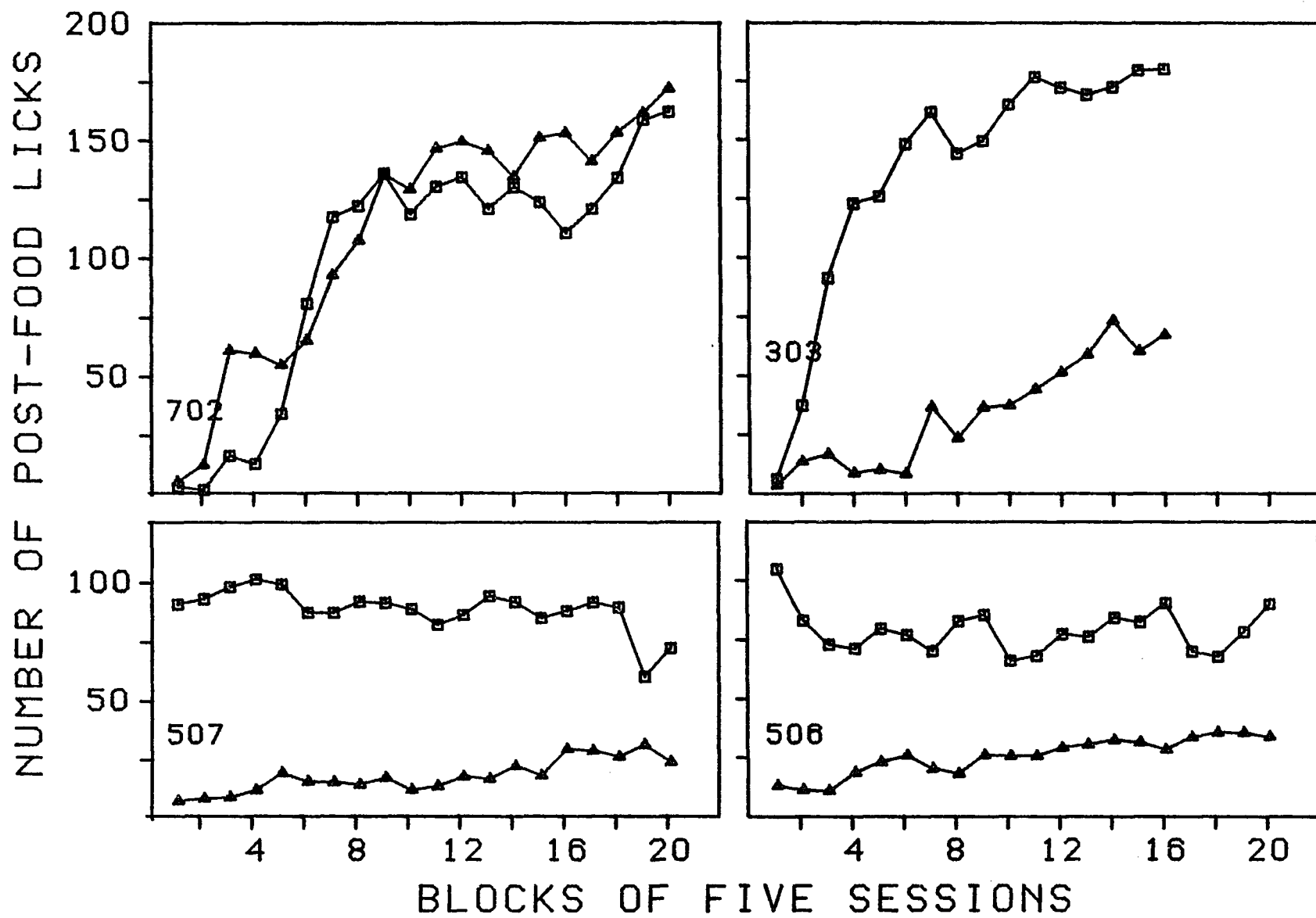


asymptote even after 100 sessions of training. Second, the manner in which the level of drinking changes with experience may be related to the conditions under which animals are trained prior to introduction of the second-order schedule. Two of the subjects whose data are shown received food-magazine and lever-press training and pre-training with the FI component of the second-order schedule (702 - FI 70 sec - 15 sessions; 303 - FI 80 sec - 12 sessions) with no water available before exposure to the second-order schedule. Two subjects (506 and 507) received food-magazine and lever-press training with water freely available, and were given no pre-training with the FI 70 sec component schedule before exposure to the second-order schedule. Subjects given pre-training without water demonstrated gradual increases in drinking levels and a gradual divergence of drinking levels during post-food and post-stimulus components. Near-asymptotic levels of drinking were present at the beginning of training with the second-order schedule for the other two subjects.

Figures 5 and 6 illustrate the manner in which licks were distributed within components. During post-food components (Figure 5), drinking occurred primarily as a post-prandial event, with the majority of licks occurring during the first half of post-food components. Subject 702 was one of the few exceptions to this generalization. That subject tended to drink at a uniform rate throughout post-food components. The post-food lick latency for that

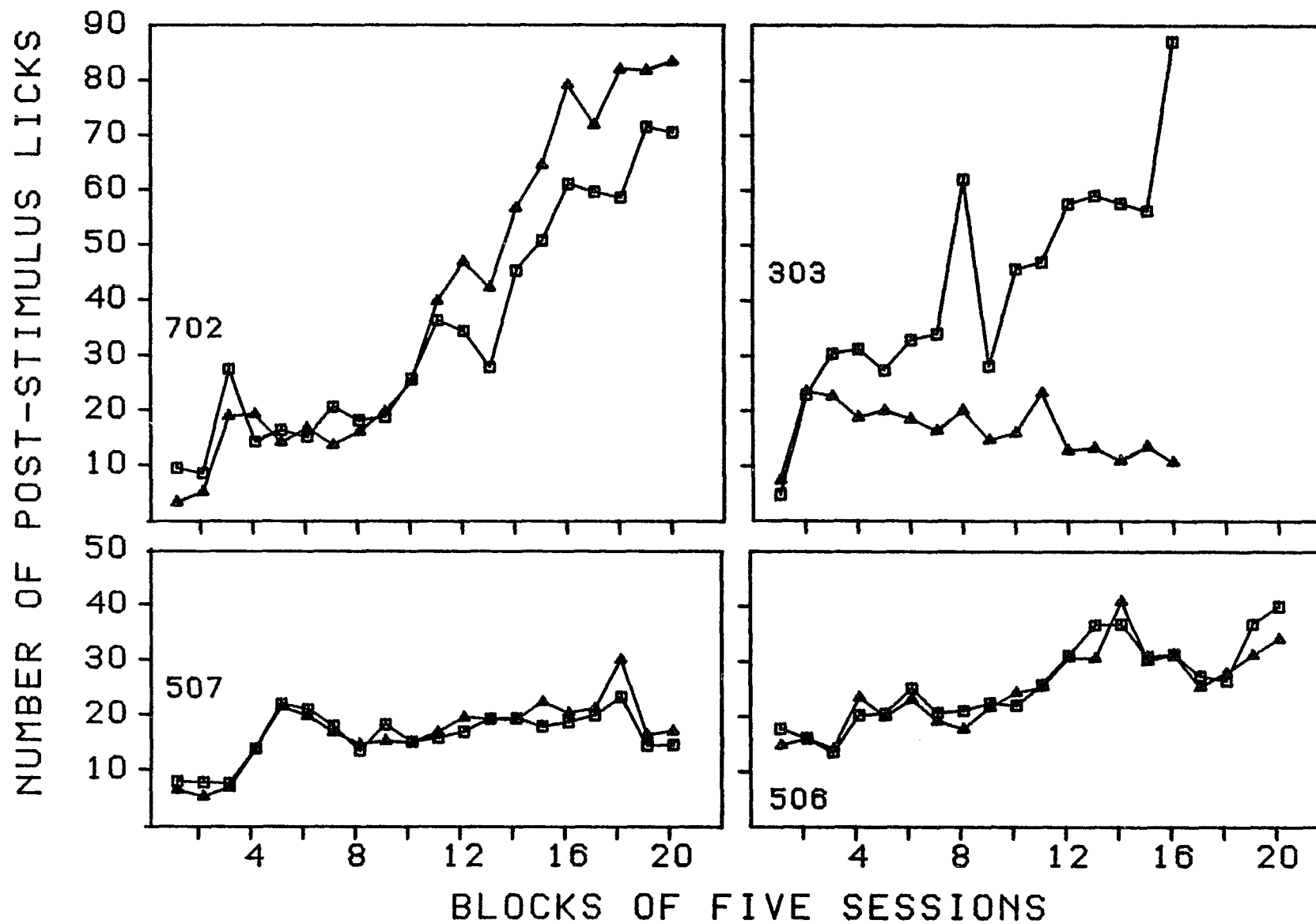
Post-Food Lick Distributions

Figure 5. Post-food lick distributions for Subjects 303, 506, 507, and 702. Squares represent mean number of licks during the first half of each component. Triangles represent mean number of licks during the second half of each component. Each point plotted represents performance averaged over five consecutive sessions.



Post-Stimulus Lick Distributions

Figure 6. Post-stimulus lick distributions for Subjects 303, 506, 507, and 702. Squares represent mean number of licks during the first half of each component. Triangles represent mean number of licks during the second half of each component. Each point plotted represents performance averaged over five consecutive sessions.



subject was also abnormal-- 15 - 25 sec vs. an average of 2 - 5 sec for other subjects. Lick patterns for the remaining subjects resemble those obtained by King and Schaeffer (1973), and are characteristic of interim behavior as described by Staddon (1977).

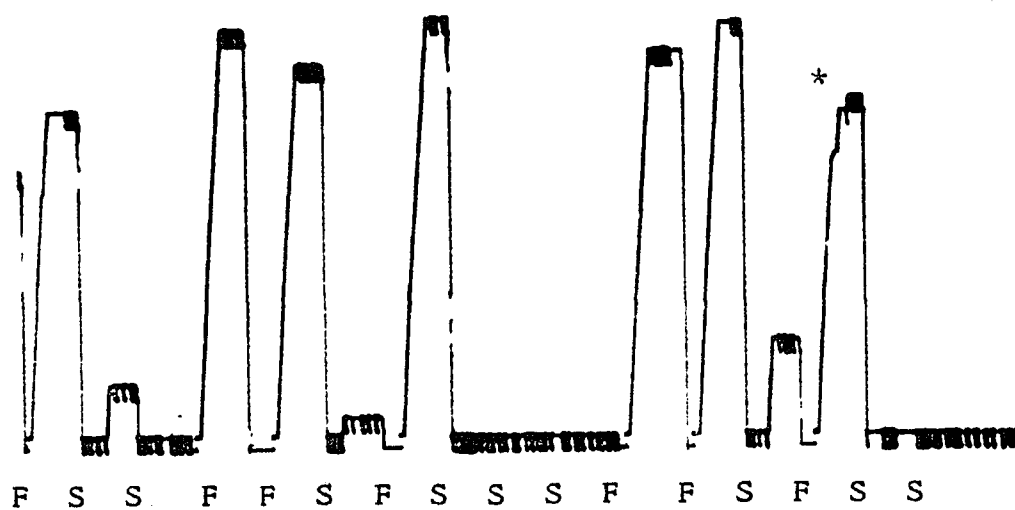
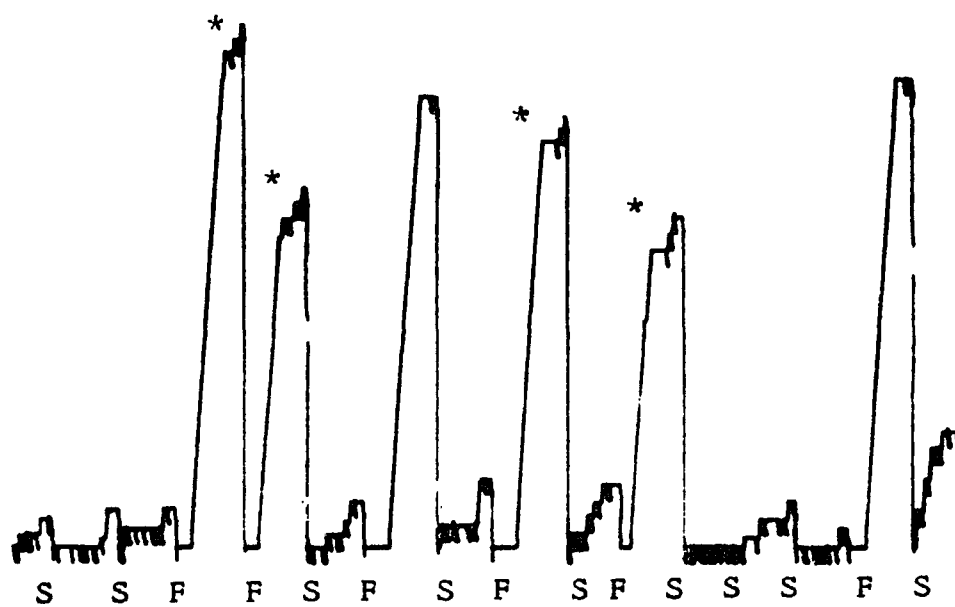
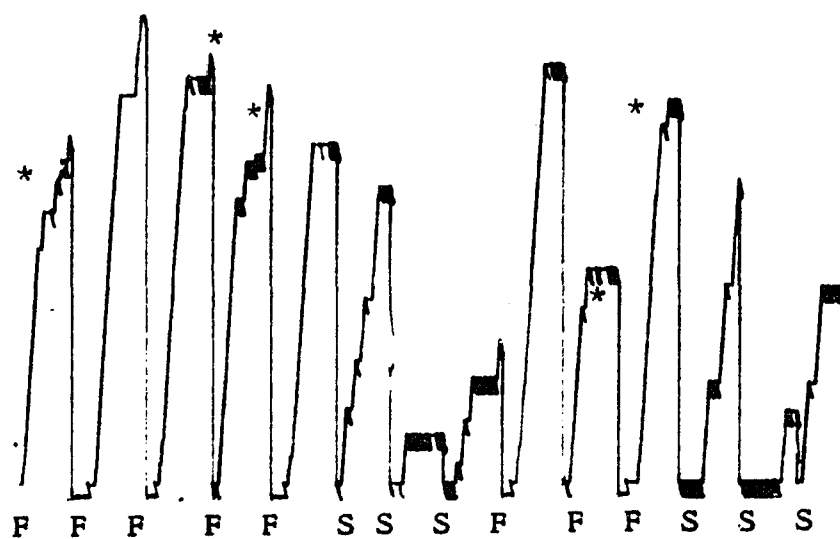
Figure 6 shows that, like lever-presses, licks were evenly distributed throughout post-stimulus components for most subjects. Again, Subject 303 was one of the few exceptions. For that subject, the general patterns of licking and lever-pressing during post-stimulus components resembled those during post-food components.

Having considered licking and lever-pressing separately, it is also necessary to consider possible relationships between the two behaviors.

The top trace in Figure 7 shows a portion of a cumulative record made during session 66 for one subject (303). The pattern of drinking during a component clearly depended upon whether a component followed a food or a stimulus presentation. Food presentations were followed by a sustained bout of uninterrupted licking. During post-stimulus components, bouts of licking alternated with bouts of lever-pressing. Post-stimulus lick bouts were much shorter than the bouts of licking which followed food-presentations. That rat frequently resumed licking following the initiation of lever-pressing during post-food components. Occurrences of the resumption of licking during post-food components, marked by asterisks, gave rise to

Sample Cumulative Records

Figure 7. Cumulative records obtained from two subjects exposed to a VR 2 (FI 80:Sn) second-order schedule. The cumulative pen recorded licks. Responses (lever-presses) are indicated by deflections of the pen. The pen was reset at the end of each component. Letters indicate food (F) and stimulus (S) presentations. Asterisks (\*) mark resumptions of drinking following the initiation of lever-pressing during post-food components.





traces which resembled the behavior patterns seen during post-stimulus components-- alternation between short bouts of licking and lever-pressing. The pattern of behavior seen in the top trace of Figure 7 was maintained by that rat for some 220 experimental sessions.

The middle and bottom traces of Figure 7 show similar cumulative records for a second subject (302). The pattern of behavior seen in the middle trace (session 15) resembled that shown in the top trace. Drinking occurred during most post-stimulus components, and frequently resumed following lever-pressing during post-food components. Post-stimulus and post-food, post-lever-press drinking gave rise to similar traces which differed from those of post-food, pre-response drinking. In the bottom trace, obtained during session 21, Drinking rarely resumed following the initiation of lever-pressing during post-food components. Post-stimulus drinking was also markedly diminished in frequency of occurrence. That subject seldom drank during post-stimulus components in the remainder of its 145 experimental sessions.

In general, rats that drank reliably during post-stimulus components tended to alternate between bouts of licking and bouts of lever-pressing, both throughout post-stimulus components and during the late portions of post-food components.

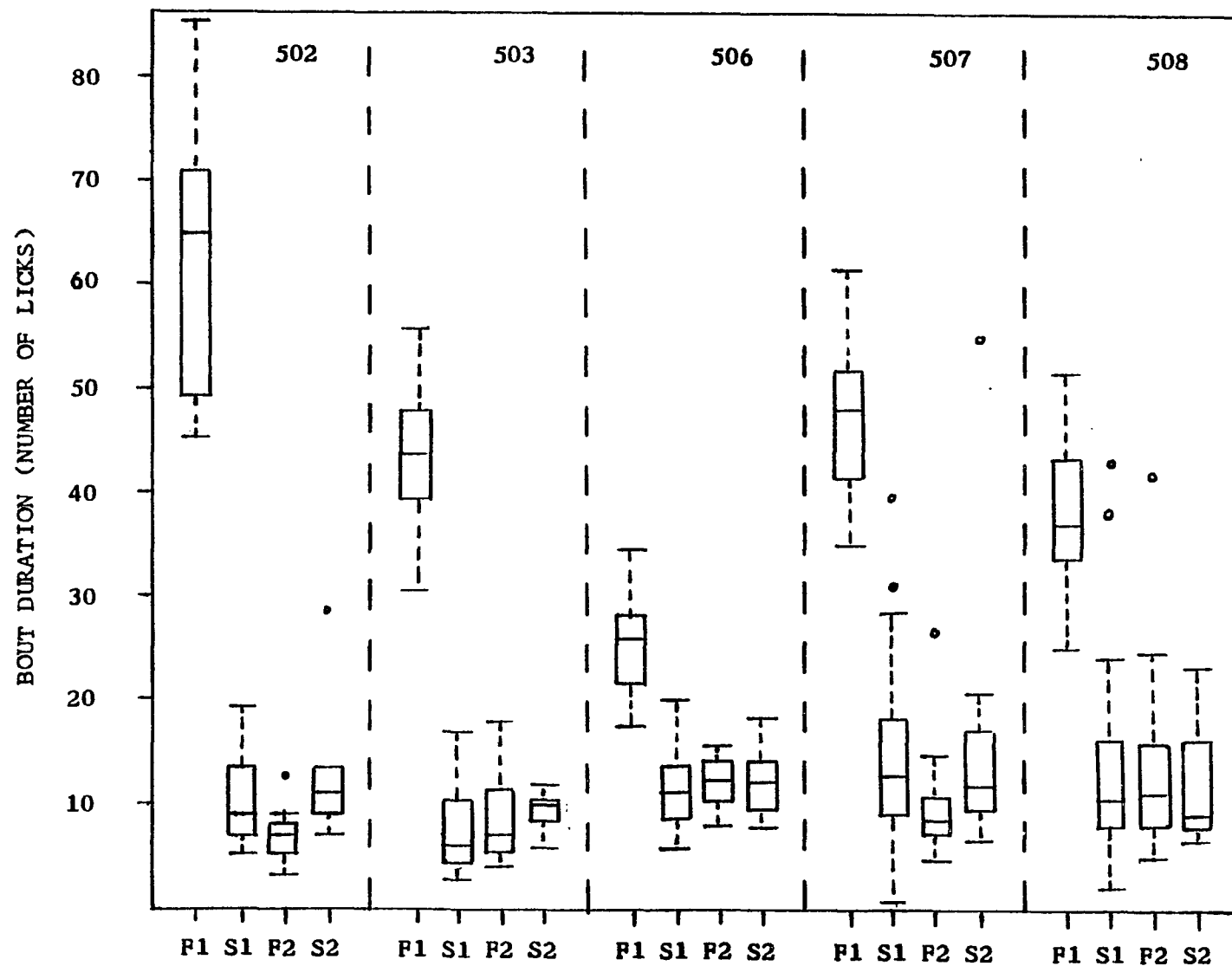
In order to quantify the difference between the various patterns of behavior seen in Figure 7, drink-bout durations were computed for a number of rats exposed to a VR 2 (FI 70:Sn) schedule. Licks were classified as post-food, pre-response (F1); post-food, post-response (F2); post-stimulus, pre-response (S1); or post-stimulus, post-response (S2).

Figure 8 compares mean bout durations for the four categories of licking. The results shown in Figure 8 are from five Harvard Brown rats, and are shown in the form of box plots (Tukey, 1977). For all five subjects, F1 bout durations were substantially longer than were F2, S1, or S2 bout durations, which did not differ among themselves.

It is thus apparent that post-food, post-lever-press (F2) drinking resembles post-stimulus drinking not only in terms of the alternation with lever-pressing, but also in terms of average bout duration. Because F2 drinking clearly differs, at least in pattern and average bout duration, from F1 drinking, it will be useful to maintain the distinction between the two.

Bout Durations

Figure 8. Box plots showing mean F1, S1, F2, and S2 bout durations (see text) obtained from 5 rats. The center line in each box is the median session-mean bout duration (number of licks). Small circles represent outliers.



### III. RESEARCH STRATEGY AND HYPOTHESES

Allen and Porter (1977) suggested that post-stimulus drinking may occur as a terminal activity, in conjunction with responding, rather than as an interim activity such as post-food drinking. Drinking could develop as a terminal activity through the same means by which responding develops. A reinforced response could follow closely upon the completion of a bout of drinking. Since reinforcement is generally thought to strengthen those behaviors which precede it, such an occurrence would increase the likelihood of drinking during the session.

But drinking never directly precedes reinforcement-- a lever-press always intervenes. It is conceivable that the circumstances of the experiment might promote the establishment of chains of behavior. The terminal link of such a chain would, of course, consist of the lever-press which actually produces reinforcement. A bout of licking might constitute the initial link. From the animal's perspective, it might be the chain of licking followed by lever-pressing which produces reinforcement. Thus we might look for the repeated emission of lick-lever-press chains. Exactly that was seen in the top and middle traces of Figure 7.

If one portion of the drinking which occurs during exposure to second-order schedules is functionally a member of a lick/lever-press chain (i.e., is terminal in nature), and if the remainder of the drinking (F1) is of a different nature, then it ought to be possible to demonstrate differences with respect to the factors by which the two types of drinking are controlled.

The purpose of Experiment 1 was to investigate the effect on drinking of a manipulation known to affect the rate of occurrence of terminal activities. If the presentation of a reinforcing event is made contingent upon the occurrence of a particular terminal activity, then the rate of occurrence of that activity ought to increase. Component termination was made contingent upon the occurrence of both lever-pressing and licking in Experiment 1. Thus the animals had to lick in order to maximize the rate at which food could be obtained.

Furthermore, the licks which set up component termination were required to occur late in each component, after the required minimum component duration had elapsed. With respect to the categories of drinking outlined earlier, such a contingency should increase the rates of occurrence of both F2 and S2 drinking, as these are the drinking categories typically observed during the latter portions of post-food and post-stimulus components respectively.

If F2 and S2 drinking belong to a class of behavior which differs from that of which F1 drinking is a member, then increased rates of F2 and S2 drinking should not be accompanied by an increased rate of F1 drinking. If these three categories of drinking are, however, members of a single class of behavior, then the rate of F1 drinking should also be increased as a result of the introduction of the contingency.

The effect of the contingency on S1 drinking is of special interest. S1 drinking resembles both F2 and S2 drinking in terms of average bout duration. Yet, like F1 drinking, S1 drinking is an early event in the component, occurring as it does prior to the onset of lever-pressing, which is often regarded as an indication of a transition on the part of the animal from an interim to a terminal state. As in the case of F1 drinking, if the rate of S1 drinking were to increase as a result of the contingency, it would be reasonable to conclude that S1 drinking belongs to the same class of behavior as do F2 and S2 drinking. However, if neither S1 nor F1 drinking rates increased as a result of the contingency, one might conclude not only that neither belongs to the same class of behavior as do F2 and S2 drinking, but also that both may, perhaps, be regarded as interim behaviors.

The objective of Experiment 2 was to provide converging evidence that some of the drinking observed when rats are exposed to second-order schedules is terminal in nature. If

signals are added to the second-order schedule so that the animal may "know" throughout each component whether that component will end with food or with a stimulus presentation, it is to be expected that higher levels of terminal behavior will be maintained during pre-food than during pre-stimulus components. If drinking (S1 and S2) occurs at a higher level during pre-food, post-stimulus components than during pre-stimulus, post-stimulus components, this would provide further evidence that post-stimulus drinking is best classified as terminal rather than as interim. For the same reason, it might be expected that F2 drinking should be maintained at a higher level during pre-food than during pre-stimulus components.

Because it reliably predicted food presentations, the pre-food signal of Experiment 2 may have acquired the properties of a conditioned stimulus (Pavlov, 1927), thereby introducing a question as to extraneous differences between the pre-food and pre-stimulus signals. Experiment 3, which explicitly examines the effects on behavior of a Pavlovian CS, has been included to permit the identification of any such effects in Experiment 2.



#### IV. GENERAL METHODS

The apparatus and procedures were adapted from Clark (1978, unpublished) because these methods produced post-stimulus drinking.

##### Apparatus

The experimental chamber measured 24 x 21.5 x 19.5 cm. The top and three of the sides were plexiglas. The front wall was aluminum and the floor consisted of a series of parallel metal rods. The chamber was situated within a larger sound-proofed enclosure. White noise was continuously presented by means of an overhead speaker to screen out extraneous sounds. A fan mounted in the side of the larger enclosure provided continuous ventilation.

A white light was mounted on the side wall of the larger enclosure, and was visible through the plexiglas wall on which the lever was mounted. Experiments were conducted with the chamber in darkness except as described below.

A food dispenser was mounted behind the aluminum wall of the experimental chamber. The food dispenser delivered 45-mg Noyes Standard food pellets to a recessed food tray (5 x 4.5 cm) mounted in the center of the aluminum wall at floor level. The food tray was accessible via a door which was hinged at the top, and which had to be swung upward

by the animal. Two holes drilled in the bottom of the food tray permitted uncollected food pellets to be dropped from the tray when a trap door was activated.

A response lever was mounted in the middle of the plexiglas wall which was to the left of the food tray. The lever was 2.5 cm wide and extended 2 cm into the chamber at a height of 3.5 cm. Water was available from a drinking tube mounted behind a 1-cm hole cut in the aluminum wall 5 cm to the right of the food tray at a height of 2.5 cm.

Electromechanical programming and recording equipment were located in an adjacent room. Licks were recorded by means of a contact sensor which passed a small current between the grid floor and the liquid in the drinking tube when the animal was in contact with both. The animal thus acted as a switch to complete the circuit. The sensor was incapable of discriminating between true licks and other behaviors of the animal, such as nose-pokes, which might serve to complete the circuit. A method to partially screen out such extraneous behaviors is described below.

#### Procedure

A random number table was used to assign the sequence of food and stimulus presentations which comprised the VR 2 (FI 70:S) second-order schedule. The schedule was so arranged that no more than four successive components had the same outcome (food or stimulus presentation).

The number of food pellets which constituted the reinforcers was varied from one food presentation to the next (mean = 3.92, range = 1 - 7). The sequence of reinforcer magnitudes was pre-assigned with the aid of a random number table. The frequencies with which the various reinforcer magnitudes occurred and the programmed sequence of food and stimulus presentations are shown in Table 1. The six points in the sequence at which sessions were allowed to begin are also shown in Table 1.

All food presentations were accompanied by illumination of the white light mounted on the side of the large enclosure. All food presentations ended with an auditory stimulus, the nature and duration of which will be specified in conjunction with the individual experiments. Simultaneous offset of the light and the auditory stimulus marked the end of each food presentation and the start of the post-food interval.

Scheduled stimulus presentations consisted of the presentation of an auditory stimulus which had the same duration as did the post-food auditory stimulus. The specific nature of this stimulus will be described in conjunction with the individual experiments.

Preliminary work indicated that some animals allowed food pellets to accumulate during presentations of multiple pellets. These animals typically ate the first pellet delivered and then drank during the remainder of the food presentation until all pellets had been delivered.

Table 1

Characteristics of the Second-Order Schedule

A. Distribution of programmed reinforcer magnitudes (number of pellets).

number  
of pellets      frequency

1	5
2	9
3	12
4	13
5	11
6	7
7	5

Mean = 3.92

B. Sequence of component types, including reinforcer magnitudes (read down columns). Digits represent reinforcer magnitudes. Lower case letters in parentheses represent various starting points. F: fcod presentations. S: stimulus presentations.

F4 (a)	F4 (b)	S	F2	S	S
F2	S	F4	S	F2	F2
F3	S	S	F3	F3	F4
S	S	S	F5	S	S
F3	S	F5	F2	F5	S
S	F4	F1	F3	S	S
F5	F3	S	S	F4	S
S	S	F2	S	F7	F7
F3	S	S	S	F6	S
F3	S	F7	F7	F1	S
F5	F4	F5 (d)	S	S	F4
F1	S	F1	F5	F2	S
S	S	F4	S	F4	F6
S	F3	S	S	S	S
S	F6	S	F6 (f)	S	F3
F2	S	F6	F4	S	S
F7	F5 (c)	S	S	F5	S
F6	S	S	S	S	F5
S	S	S	S	F3	F1
S	S	S	F3	S	F4
F6	F2	F4 (e)			

Occasionally, the accumulated pellets were not eaten until well into the succeeding post-food period. To prevent this, a trap door was mounted in the floor of the food tray. Opening of the trap door allowed most accumulated food pellets to drop out of the tray so that the animal would not have access to them. The trap door was operated briefly once or twice during food presentations, but only if the access door of the food tray was closed. The animal therefore had to keep its head inside the tray during food presentations to obtain its full ration of pellets. The sequence of trap door openings and pellet deliveries during food presentations was determined by means of a coded tape read by a tape reader. The tape was advanced during food presentations according to a RT 0.46-sec schedule ( $p = 0.65$ ,  $t = 0.3$  sec).

Each session began with a food presentation and ended with the completion of the first food presentation to occur after the session timer had timed out. Session durations will be specified in conjunction with the procedural details of individual experiments. Sessions were conducted daily. Initial training of subjects always began during July.

#### Response Data

The response required during all response-dependent conditions was a depression of the lever mounted in the chamber. Total responses and their distribution over time were recorded separately for post-food and post-stimulus components. Response latencies were recorded from the onset

either of the post-food auditory stimulus or of the auditory food-omission stimulus. Data recorded on time meters were used to compute average component durations. Response rates were computed by dividing average responses per component by the difference between average component duration and average response latency.

#### Lick Data

Lick counters were activated by the occurrence of a series of at least three tube contacts within a time span of 0.75 sec. The counters remained active until 1.2 sec elapsed without a tube contact. This method for recording licks was found to be moderately successful in screening out tube contacts by means other than licking.

Total licks and their distribution over time were recorded separately for post-food and post-stimulus components. Lick latencies were recorded from the onset either of the post-food auditory stimulus or of the auditory food-omission stimulus, and were adjusted to eliminate time accumulated on the counters during components in which the animal failed to lick.

A lick bout was defined as beginning with an activation of the counters and ending with the deactivation of the counters. Total bouts were recorded separately for post-food and post-stimulus components. Bout durations (measured as mean number of licks per bout) were computed.

Lick-bout initiation rates were computed by dividing total bouts by estimated time during which an animal was not actually drinking. This was done to permit an assessment of the effects of various manipulations unconfounded by changes in the amount of time available for drinking.

A record was also made of the proportion of components of each type during which at least one bout of licking occurred.

The following lick data were further broken down according to whether they occurred before or after the initiation of lever-pressing during each component: total licks, total lick bouts, average bout duration, and rate of lick bout initiation.

Numerical data for both licking and lever-pressing were supplemented by cumulative records.

## V. EXPERIMENT 1: CONTINGENCY EFFECTS

Several investigators have reported effects of various contingencies on schedule-induced drinking with simple schedules. Both Flory and Lickfett (1974) and Moran and Rudolph (1980) found that interim drinking can be reduced in extent by the imposition of a reinforcement delay contingent upon the occurrence of drinking. Longer delays gave rise to greater reductions in drinking. The data do not permit an analysis of the mechanism whereby drinking was reduced (i.e., shorter bouts, fewer bouts, etc.) Data reported by Reberg (1980) suggest that, at least early in training, lick latencies may be sensitive to various sorts of contingencies. There have been no investigations of the effects of contingencies on licking with second-order schedules.

In the present experiment, experienced animals were exposed to a condition in which they were required to emit at least three licks 70 sec or more after the start of each component before a lever-press could terminate the component and produce either food or a stimulus presentation.



### Experiment 1a

#### Method

Subjects. Two male Harvard Brown rats (W. M. Baum, UNH) were maintained at 80% of their ad lib weights. Both were approximately six months of age at the start of the experiment. Each had received 52 sessions of training with the baseline schedule prior to introduction of the contingency on licking.

Procedure. The baseline schedule was VR 2 (FI 70:Sn). The stimulus presented when food was omitted was a 2-sec tone. A 2-sec repetitive click followed each food presentation.

The basic procedure was modified so that termination of a component required that at least three licks occur 70 sec or more after the component began before a response could terminate the component and produce food or a stimulus presentation. The required licks were not screened, so that three isolated tube contacts were as effective as a burst of licks in setting up the consequence for a response.

The contingency remained in effect for 20 sessions, after which the animals were returned to the baseline (no contingency) condition. Sessions lasted approximately 55 min.

## Results

Figure 9 shows both lick bout initiation rates and bout durations for the two subjects. A clear effect of the lick contingency on lick-bout initiation rates can be seen in the top panel. F2, S1, and S2 rates were elevated while the contingency was in effect. F1 rates were slightly depressed in the presence of the contingency.

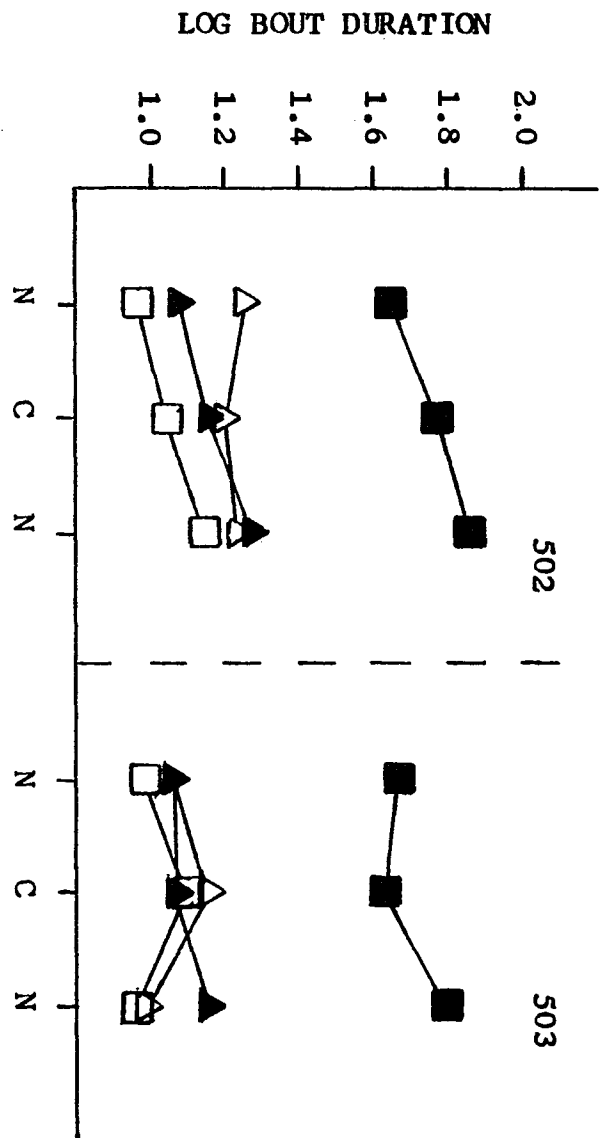
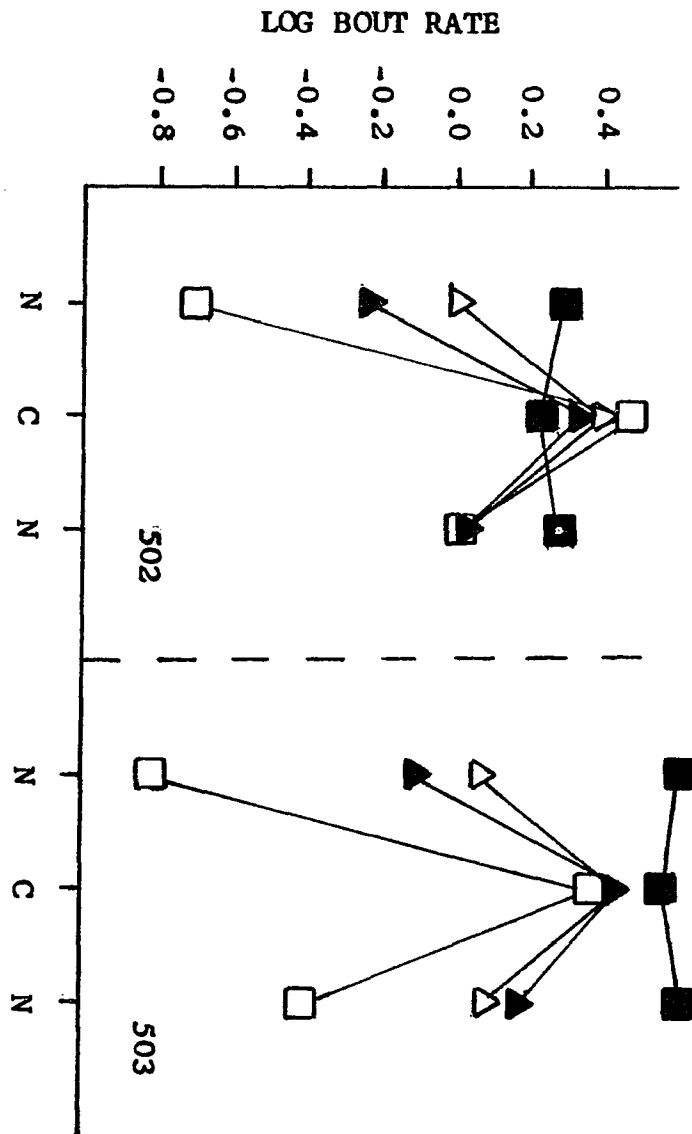
The contingency had no consistent effect on bout durations (Figure 9, bottom panel). The data for Subject 502 indicate a general increase in bout duration over the course of the experiment for F1, F2, and S1 licking. Changes in bout duration were uncorrelated with experimental conditions for #502. For Subject 503, a slight elevation of F2 and S2 bout durations was evident while the contingency was in effect. The bout duration data shown in Figure 9 are consistent with the data shown in Figure 8-- F1 bout durations were consistently longer than were F2, S1, or S2 bout durations. This difference was independent of bout initiation rates.

## Experiment 1b

This experiment was intended to replicate the results of the previous experiment with a larger number of subjects and with a slightly modified contingency. The contingency for the present experiment required that the three licks which set up the consequence for a lever-press occur as a single bout. It was expected that this additional requirement would insure that only true licking would be

### Experiment 1a: Results

Figure 9. Effect of the lick contingency (Experiment 1a) on bout initiation rates (top panel) and bout lengths (bottom panel). Both bout rates and bout lengths have been represented by logarithmic scales. Filled squares-- F1 rates/durations; open squares-- F2 rates/durations; filled triangles-- S1 rates/durations; open triangles-- S2 rates/durations.



reinforced.

#### Method

Subjects. Two male Harvard Brown rats (502 and 503) used in the previous experiment and three male albino rats (CD-- Charles River) were maintained at 80% of their free-feeding weights. All rats were aged approximately 7-8 months at the start of the experiment.

The brown rats had received 26 sessions of baseline training following the completion of Experiment 1a. The present experiment thus began during session 109 of training for those rats.

The three albino rats also had extensive experience with the baseline schedule. Two albino rats (703 and 704) began the present experiment during session 98 of training. One albino rat (707) began the present experiment during session 84.

Procedure. The procedure of Experiment 1a was modified so that the three licks which made possible the termination of a component were required to occur as a single bout.

Sessions lasted approximately 55 min. The contingency remained in effect for 30 sessions for subject 707. All other subjects received 25 sessions of training with the contingency in effect.

### Results and Discussion

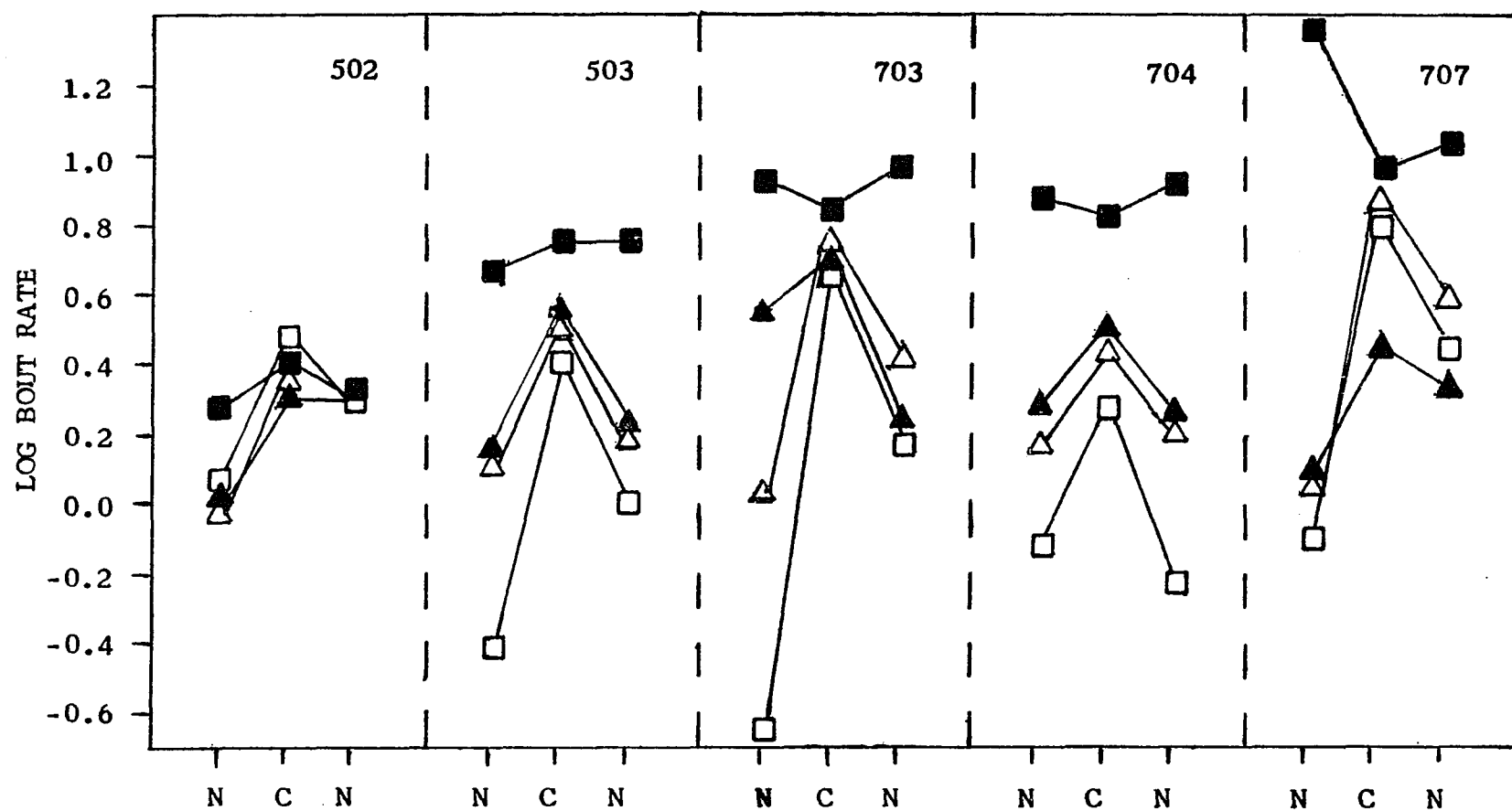
The results of the present experiment are consistent with those of Experiment 1a. Bout initiation rates are shown in Figure 10. F2, S1, and S2 lick bout rates were clearly elevated while the contingency was in effect. There was no consistent effect of the contingency on F1 bout rates.

Figure 11 shows mean bout durations for the 5 subjects. As in the previous experiment, there was no consistent effect of the contingency on bout durations. The greater duration of F1 bouts as compared to F2, S1, and S2 bouts is quite clear.

Sample cumulative records are presented in Figure 12. These records represent the performance of Subject 703 during the 23rd session with the contingency in effect (top panel), and during the 9th session after the contingency had been removed (bottom panel). The cumulative (upper) trace in each panel recorded licks. Deflections of the cumulative pen indicate lever-presses. The lower pen was deflected during post-food components. The recording pens were activated by the first lever-press during each component. Thus, the long bouts of licking which typically follow food presentations have been omitted from these records. The top panel shows quite clearly that, with the contingency in effect, short bouts of licking alternated with bouts of lever-pressing. The alternation between licking and lever-pressing occurred at a respectable rate throughout

Experiment 1b: Bout Rates

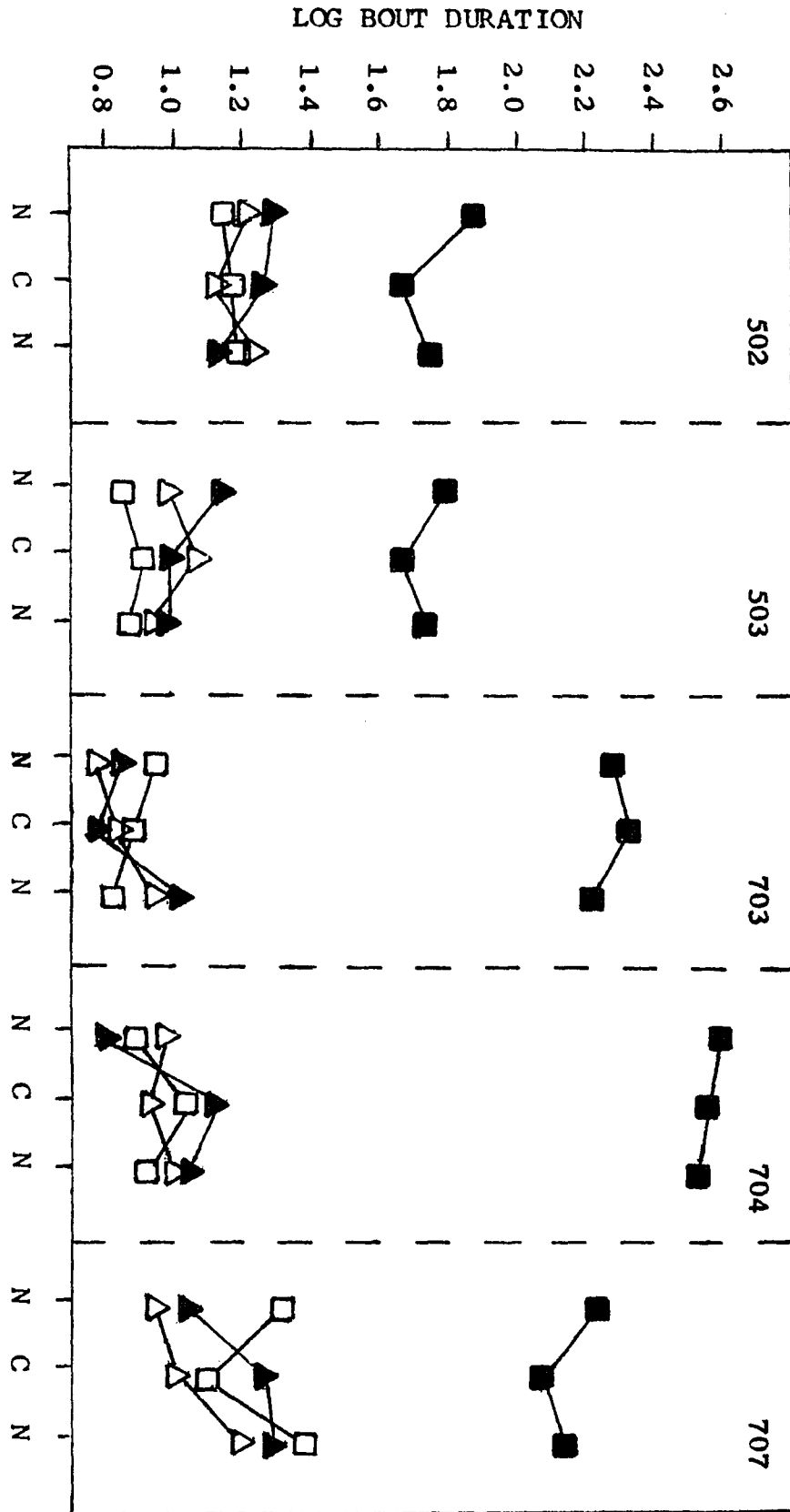
Figure 10. Effect of the lick contingency of Experiment 1b on bout initiation rates. Bout initiation rates are represented by means of a logarithmic scale. Filled squares-- F1 rates; open squares-- F2 rates; filled triangles-- S1 rates; open triangles-- S2 rates.





Experiment 1b: Bout Durations

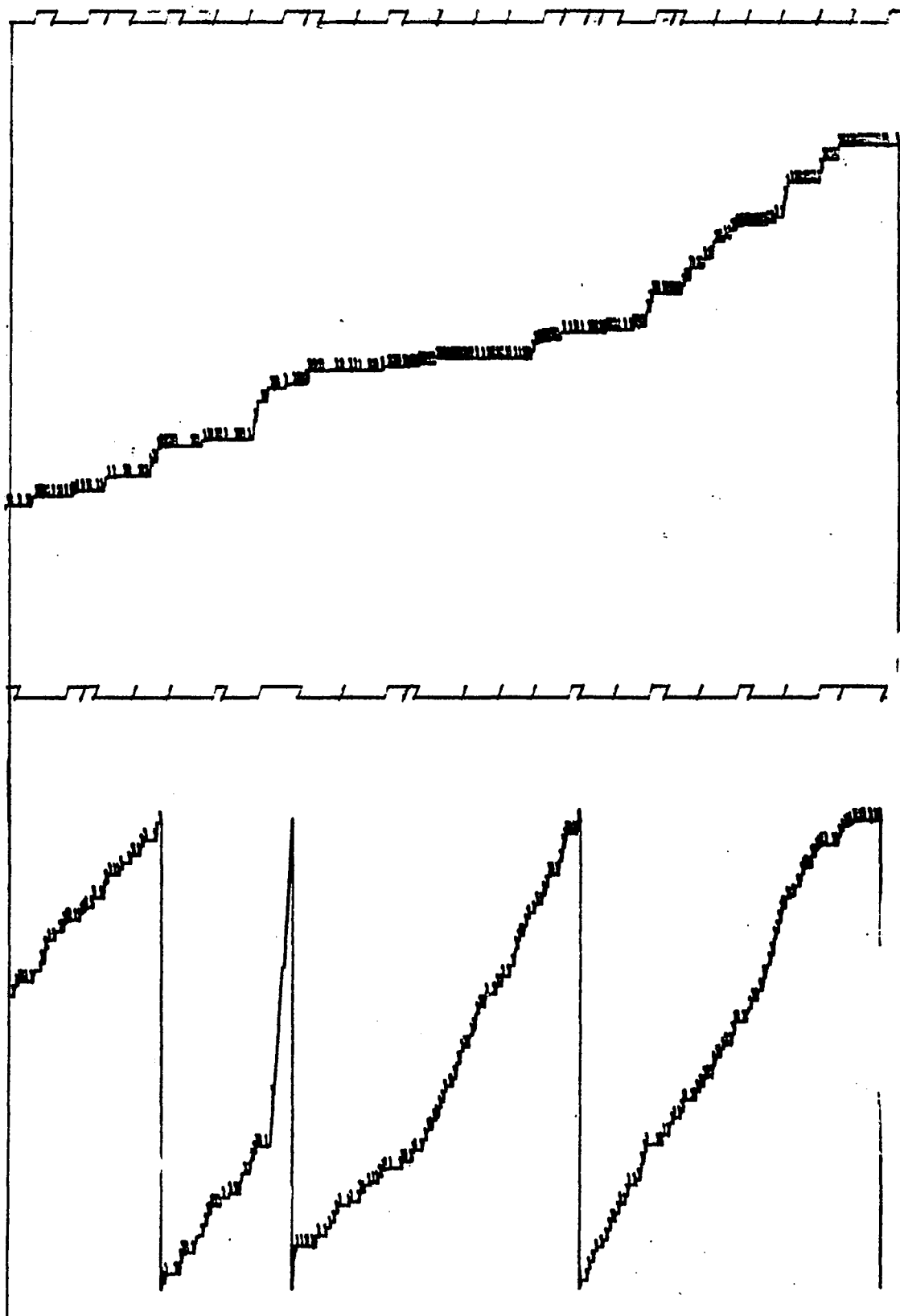
Figure 1-1. Effect of the lick contingency of Experiment 1b on bout durations. Bout durations are represented by means of a logarithmic scale. Filled squares-- F1 bout durations; open squares-- F2 durations; filled triangles-- S1 durations; open triangles-- S2 durations.



Experiment 1b: Sample Cumulative Records

Figure 12. Cumulative records obtained from Subject 703. The cumulative pen records licks. Lever-presses are indicated by deflections of the cumulative pen. The lower pen in each panel was deflected during post-food components. The recording pens were activated by the first lever-press to occur during each component. Top panel: Session 23 with the contingency in effect. Bottom panel: Session 9 after removal of the contingency.

A burst of F'-like licking was captured in the center of the top trace, perhaps because the animal backed into the response lever before drinking. The difference between that style of drinking and the short-bout style most commonly pictured is evident.



post-stimulus components. The effect of the contingency, therefore, was more pervasive than a forcing of drinking late in components. Rather, the contingency seems to have promoted a general increase in the rate of licking in conjunction with lever-pressing. Much of the drinking captured in the top panel of Figure 12 disappeared soon after the contingency was removed, resulting in a lower slope for the cumulative record in the lower panel. It is a common occurrence for behaviors maintained by a contingency to diminish in rate upon removal of the contingency.

#### General Discussion of Experiment 1

The data extend earlier observations of contingency effects on schedule-induced drinking (Flory and Lickfett, 1973; Moran and Rudolph, 1980; Reberg, 1980) by suggesting one mechanism whereby a contingency may affect drinking. In the present experiment, introduction of a contingency which required that licking occur raised levels of drinking by increasing the rate at which lick bouts of short duration (F2, S1, and S2) were initiated. The contingency did not affect lick bout durations.

Previous investigators of contingency effects on schedule-induced drinking have made use of simple schedules. Future research might profitably be directed toward determining whether the mechanism by which drinking levels increased in the present experiment could account for contingency effects in simple schedules.

In the context of the present dissertation, the data show that, with regard to controlling factors, F1 drinking differs in at least one respect from F2, S1, and S2 drinking. Rates of bout initiation for the latter types of drinking were elevated in the presence of a contingency on licking. F1 bout rates were relatively insensitive to the contingency, and in several cases were slightly depressed while the contingency remained in effect.

Further, S1 drinking resembled F2 and S2 drinking with respect to the increased rate of occurrence while the contingency remained in effect. It may therefore be meaningful to regard F2, S1, and S2 drinking as elements of a single class of drinking different from the class of drinking of which F1 drinking is a member.

## VI. EXPERIMENT 2: EFFECTS OF SIGNALLED OUTCOMES

Experiment 1 demonstrated a facilitatory effect of a lick contingency on the rates of F2, S1, and S2 lick bout initiations. That effect did not extend to F1 lick bout rates. Since two types of drinking were distinguished on the basis of the effect of the contingency, it is appropriate to inquire into the respective natures of these types of drinking.

The sustained, uninterrupted bouts of licking characteristic of F1 drinking have been observed only during post-food components. Therefore, F1 drinking presumably occurs as a response to food ingestion.

It was speculated earlier that drinking which alternates with lever-pressing may occur as the first element of a complex behavioral chain, the second element of which is the performance of the behavior actually required for reinforcement. Some informal observations made following the completion of Experiment 1 suggested that such is not the case. When the response lever was removed from the chamber, drinking behavior was relatively unaffected. Post-stimulus bout durations and rates resembled those observed when the lever was present. If post-stimulus drinking were chained with lever-pressing, then removal of the lever ought to have resulted in some disruption of the

drinking. Since that was not the case, an explanation for the alteration between drinking and lever-pressing during post-stimulus components and during the latter portions of post-food components must be sought elsewhere.

Lever-pressing might be regarded as a (terminal) behavior which occurs in anticipation of food presentations for two reasons. First, lever-pressing gradually ceases during extinction when reinforcement is discontinued. Second, when food presentations occur at regular intervals, as in Fixed Interval schedules, it is usually the case that response rates increase late in the interval as a food presentation approaches. The same is seen during post-food components of second-order schedules. By contrast, however, response rates remain approximately constant throughout post-stimulus components. Animals typically emit roughly as many responses early during post-stimulus components as late in such components. Observations of post-stimulus lick distributions (Figure 6) show that licks, like lever-presses (Figure 3), tend to be evenly distributed during post-stimulus components.

It may be the case that both post-stimulus and F2 drinking are controlled, like lever-pressing, by the animal's anticipation of food. In addition to the similarities in post-stimulus patterns described above, there are data, obtained under ad lib conditions (Kissileff, 1969), which indicate that rats drink large amounts of water before, as well as after, eating. F2, S1, and S2 drinking



may reflect the animal's tendency to drink before eating, while F1 drinking may reflect the animal's tendency to drink after eating.

Experiment 2 was designed to test the effect of the anticipation of food presentations on drinking during exposure to second-order schedules. The basic schedule was modified so that auditory signals presented throughout each component informed the animal as to the outcome (food or stimulus presentation) scheduled to follow that component.

In considering possible results of this experiment, it is necessary to describe components not only with respect to the events with which they begin, but also with respect to the events with which they end. Table 2 provides a classification of the various component types and the designations which will be applied to each. Basically, an initial letter indicating the scheduled outcome for each component has been added to the designations used in Experiment 1. As an example, pre-food, post-stimulus components will be designated FS.

Assuming that F2, S1, and S2 drinking reflect the anticipation of food presentations, each of these types of drinking should occur at higher levels during pre-food components than during pre-stimulus components. It is also to be expected that lever-press rates will be higher during pre-food components than during pre-stimulus components. Thus it will be informative, not only to look for differences in drinking between pre-food and pre-stimulus

Classification of Components and Lick Categories

Table 2. Digits represent before and after responding.  
First letter represents event with which component ends.  
Second letter indicates event with which component begins.

		!		!		!		!	
		!	Pre-Response	!	Post-Response	!		!	
		!		!		!		!	
		!	-----			-----			!
		!		!		!		!	
		!	Post-	!	Post-	!		!	
		!		!		!		!	
		!	-----			-----			!
		!	Food	!	Stimulus	!	Food	!	Stimulus
		!		!		!		!	
-----		!	-----			-----			!
!	!	!		!		!		!	
!	!	!	Food	!	FS1	!	FF2	!	FS2
!	!	!		!		!		!	
!	Pre-	!	-----			-----			!
!	!	!		!		!		!	
!	!	!	Stimulus	!	SF1	!	SF2	!	SS2
!	!	!		!		!		!	
!		!		!		!		!	

components, but also to examine differences in lever-press rates. Pre-food/pre-stimulus differences in lever-pressing would demonstrate that animals are capable of discriminating between the signals to be used, even if no differences are found with respect to drinking. Also, since lever-pressing is regarded as terminal behavior, a pre-food/pre-stimulus difference in drinking which parallels that found for lever-press rates would suggest that F2, S1, and S2 drinking ought to be classified as terminal activities.

The expected response rate differences between pre-food and pre-stimulus components might have the effect of lengthening pre-stimulus components relative to pre-food components. This would be undesirable because schedule-induced drinking is known to be sensitive to component duration (Falk, 1969, 1971; Flory, 1971), thus making possible an alternative explanation for the expected results. It would be possible to avoid this problem by scheduling food and stimulus presentations to occur independently of the animals' behavior (Fixed Time schedule). Corfield-Sumner, Blackman, and Stainer (1977), however, found much less post-stimulus drinking among animals exposed to response-independent second-order schedules than among animals exposed to equivalent response-dependent schedules.

In the present experiment, the majority of animals were exposed to a response-dependent schedule. Several animals were, however, exposed to a response-independent schedule.

It was hoped that any differences between pre-food and pre-stimulus drinking observed with the former group of animals would be reflected, though perhaps in attenuated form, among animals in the latter group. This would rule out an explanation of the anticipated pre-food/pre-stimulus behavior differences on the basis of unequal component durations.

Finally, a group of control animals was run in a response-dependent condition from which the signals were omitted, thereby permitting comparison of the results with the data described under Preliminary Research. This seemed advisable for two reasons. First, the level of food deprivation employed in the present experiment was somewhat greater than was used previously. There are data to suggest that levels of schedule-induced drinking may increase with increases in food-deprivation level (Falk, 1971). Second, the animals were somewhat older at the start of the experiment than had usually been the case. It is unknown whether this might have a bearing on the results.

#### Method

##### Subjects

Twelve male albino rats (CD-- Charles River), aged 4 months at the start of the experiment, were maintained at 70% of their free-feeding weights.

### Procedure

A VR 2 (FI 70:Sb) second-order schedule was used in all response-dependent conditions. A VR 2 (FT 70:Sb) schedule was used for the response-independent conditions. The stimulus presented at the end of food deliveries and upon food omissions consisted of a 2.5-sec increase in the intensity of the background white noise.

A tone and a repetitive clicking sound served as signals regarding the outcomes scheduled for the various components. These were counterbalanced as to information content. One of the two signals was present, for the experimental animals (801 - 809), at all times except during food and stimulus presentations. Initially, animals in the control group (810 - 812) were not presented with these signals.

Exposure to the second-order schedule began immediately after lever-press training for animals in the response-dependent conditions (801 - 806, 810 - 812), and immediately upon completion of food-magazine training for animals in the response-independent conditions (807 - 809). The sequence of training conditions for all subjects is given in Table 3. The scheduled session length was approximately 45 min.

### Experimental Conditions

Table 3. Symbols to the left in each entry represent signal conditions. Symbols to the right in each entry represent the schedule in effect during each phase. Symbols are explained below. The duration for each phase (number of sessions) is shown in the right-hand column of the table.

Schedule Conditions: FI-response-dependent condition [VR 2 {FI 70:Sb)], FT-- response-independent condition [VR 2 {FT 70:Sb)]; Informative Signal Conditions: S1-- pre-food click/pre-stimulus tone, S2-- pre-food tone/pre-stimulus click; Uninformative Signal Conditions: NC-- no correlation between signals and component outcomes, NS-- unsignalled outcomes (no signals).

Experimental Subjects

Phase	801-803	804-806	807	808-809	Duration
1	S1-FI	S2-FI	S2-FT	S1-FT	48
2	NC-FI	NC-FI	NC-FT	NC-FT	32
3	S2-FI	S1-FI	S1-FT	S2-FT	48

Control Subjects

Phase	810	811-812	Duration
1	NS-FI	NS-FI	75
2	NC-FI	S2-FI	35

Phase 1 (see Table 3) constituted the experiment as designed. Results at the end of Phase 1 (see below) were not as anticipated. Consideration of the results from Phase 1 necessitated the inclusion of Phases 2 and 3. During Phase 2, all animals which had received component-outcome signals during Phase 1 continued to receive those signals, but the correlation between signals and component outcomes was eliminated. Phase 3 constituted a reinstatement of a correlation between signals and component outcomes, but with the information content of the signals reversed from that of Phase 1. Thus for those animals for which the tone had preceded food presentations in Phase 1, the click preceded food presentations during Phase 3.

Control animals were run for 75 sessions without outcome-signals. Additional aspects of the treatment of control animals are described in Experiment 3b. After the initial phase, Subjects 811 and 812 were transferred to a signalled-outcome condition (Table 3) similar to that to which experimental animals were exposed in Phases 1 and 3. Subject 810 was presented, after the initial 75 sessions, with signals uncorrelated with scheduled component outcomes as was done during Phase 2 for the experimental animals. Control subjects were run under the latter set of conditions for 35 sessions.

Data. In addition to the measures of lever-pressing described under General Methods, discriminative indices (Millenson, 1967) and indices of curvature (Fry, Kelleher,



and Cook, 1960) were computed.

Discrimination indices (DI's) were computed separately for post-stimulus and post-food components by dividing pre-food lever-press running rates by the sum of pre-food and pre-stimulus rates. The DI would thus approach 1 when pre-food rates were much higher than pre-stimulus rates, and would approach 0 when pre-stimulus rates greatly exceeded pre-food rates.

The index of curvature (IC) provides a single-number description of the temporal distribution of behavior within components. Under the data-recording conditions of the present experiment, the IC would have a value of +0.5 if all lever-presses occurred during the second half of a component, and a value of -0.5 if all lever-presses occurred in the first half of a component. A value of 0 would indicate that lever-presses were evenly distributed within components. It should be emphasized that the IC is an index of the distribution, rather than of the level or rate of occurrence, of a particular behavior. During preliminary research, the IC for lever-pressing was typically near 75% of the maximum positive value during post-food components, and close to 0 for post-stimulus components.

IC's were also computed for lick distributions. The range of possible values was identical to that for lever-pressing. During preliminary research, post-food IC's were seldom more than half the maximum negative value, while post-stimulus IC's were typically near 0.

### Results

The presentation of results will be organized as follows. Lever-pressing performance will be described first in order to demonstrate the acquisition of a pre-food/pre-stimulus discrimination among experimental animals during Phase 1 of the experiment. Changes in lever-press performance during Phase 2 will be described, as will recovery of performance during Phase 3. Following the description of lever-press performance, drinking will be described, first at the relatively superficial level of licks per component, and then at more refined levels-- pre- and post-response drinking levels, bout durations and rates, lick latencies, and lick distributions. Statistical analyses are included as a convenient means to summarize the principle sources of variability in the data. It will be seen that few reliable differences between pre-food and pre-stimulus drinking were present at the end of Phase 1. These were generally not statistically significant, and were typically eliminated during Phase 2 and not recovered during Phase 3. Observations not described in detail in this section are given more detailed presentation in Appendix A.

Lever-press rates at the end of Phase 1 (averaged over sessions 45 - 48 for Subjects 801 - 806, 810 - 812) were subjected to a multiple regression analysis (MRA, Kerlinger and Pedhazur, 1973). The results of the MRA, shown in Table 4, revealed a clear effect of the type of outcome signalled. Pre-food rates were significantly higher than pre-stimulus

rates [ $F(1,18) = 19.7$ ,  $p < .01$ ,  $r\text{-squared} = 0.43$ ]. The presentation of signals had no effect on lever-press rates; neither did the events with which components began, nor the interaction between those events and types of outcomes signalled.

Discrimination indices for the 6 subjects in the response-dependent experimental condition (Subjects 801 - 806) are presented in Figures 13 and 14. These figures reveal several noteworthy features of lever-pressing performance. First, a discrimination between pre-food and pre-stimulus signals was more strongly evidenced during post-food (FF and SF) than during post-stimulus (FS and SS) components for all subjects at the end of Phase 1. Second, during Phase 2, both post-food and post-stimulus DI's declined. Several subjects (801, 802, 804, 806) demonstrated a more persistent retention of the Phase 1 discrimination during post-food than during post-stimulus components of Phase 2. Subject 806 was peculiar in demonstrating a partial recovery of the post-food discrimination late in Phase 2. Post-stimulus DI's at the end of Phase 2 were comparable to those observed at the beginning of Phase 1. Post-food DI's were, in many cases, somewhat higher at the end of Phase 2 than at the beginning of Phase 1. Third, acquisition of a reversed discrimination

Analysis of Effects on Phase 1Lever-Pressing

Table 4. Lever-press rates, averaged over sessions 45 - 48, were subjected to a Multiple Regression Analysis.

Note

1. Vectors used made the following comparisons: A-- behavior during signalled pre-food components vs. behavior during signalled pre-stimulus components; B-- behavior during post-food components vs. behavior during post-stimulus components; C-- behavior among subjects presented with signals (801 - 806) vs. behavior among subjects not receiving signals (810 - 812); and D-- behavior among subjects presented with signal pair S1 (801 - 803) vs. behavior among subjects presented with signal pair S2 (804 - 806).

Table 4Multiple Regression Analysis:Phase 1 Lever-Press Rates

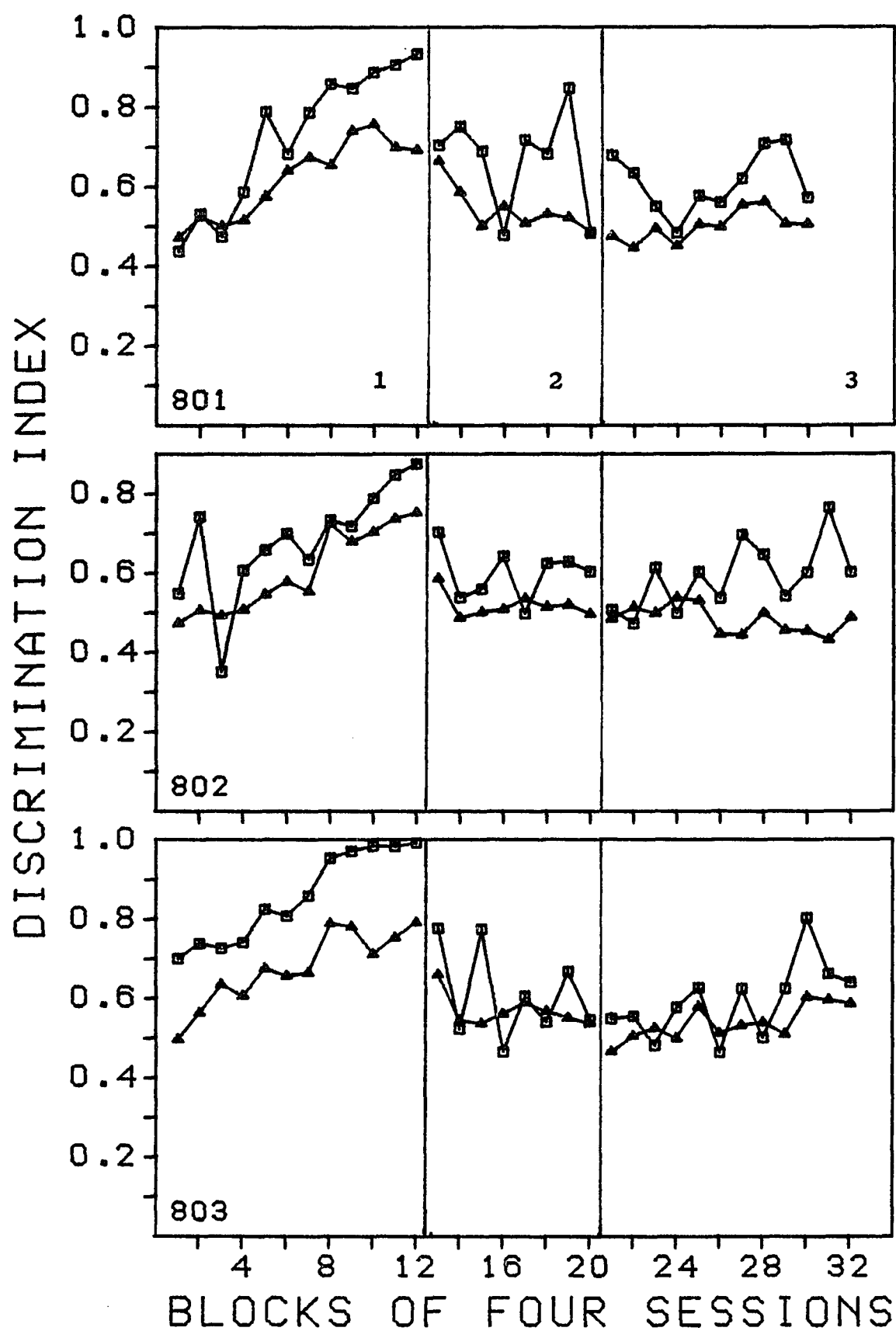
Source (1)	df	SS	MS	F	r-Squared
A. Pre F/S	1	5710	5710	19.7**	0.43
B. Post F/S	1	232	232	1.3	0.02
C. Signal	1	1	1	0.0	0.00003
D. Sig. Pair	1	71	71	0.2	0.01
Interaction					
A x B	1	353	353	1.2	0.03
Residual	24	6954	290		
Total	29	13321			0.48

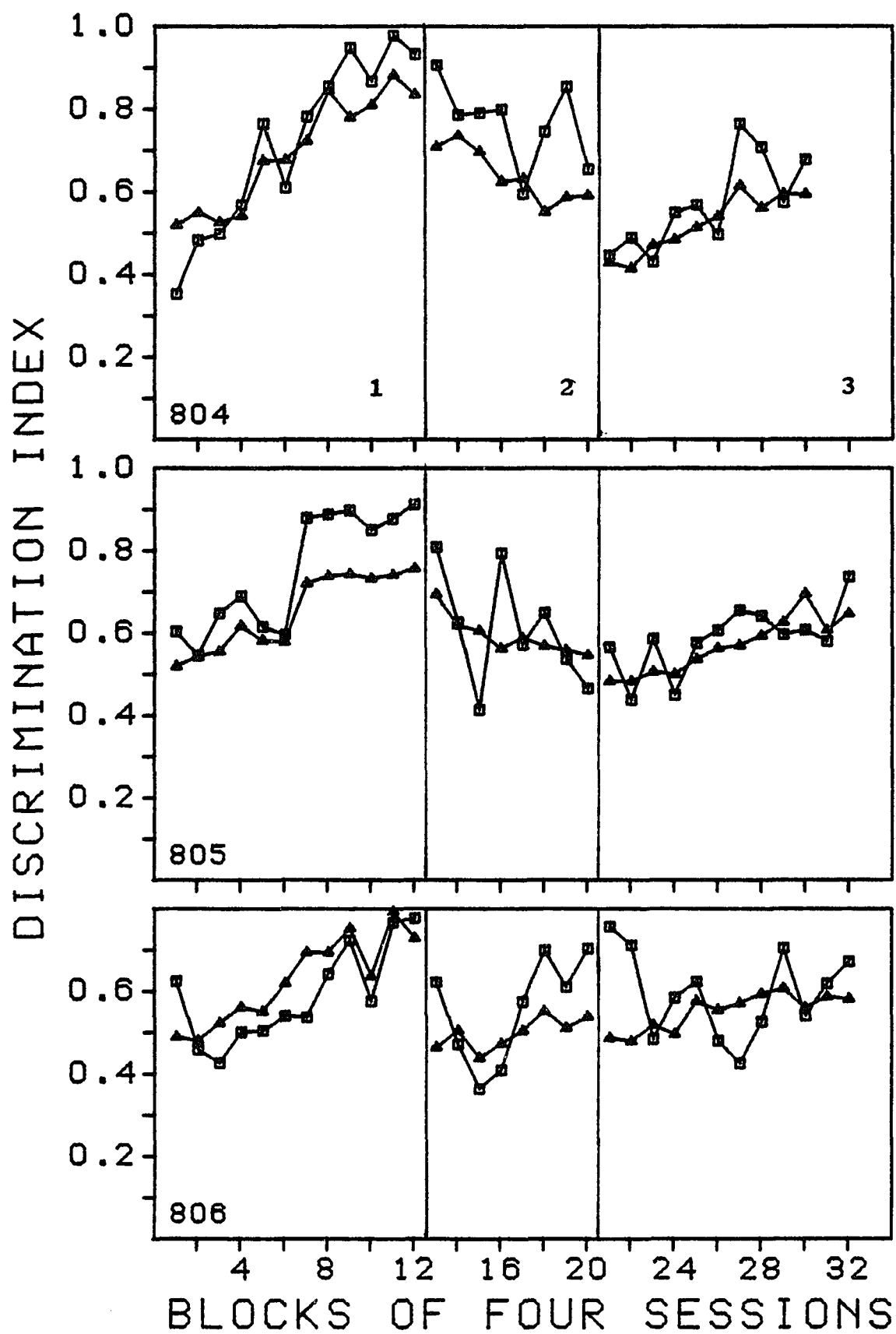
\*-- p &lt; 0.05

\*\*-- p &lt; 0.01

### Discrimination Indices

Figures 13 and 14. Data represent discrimination indices, as described under Method, for the 6 subjects in the response-dependent experimental condition (901 - 806). Phases of the experiment are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.







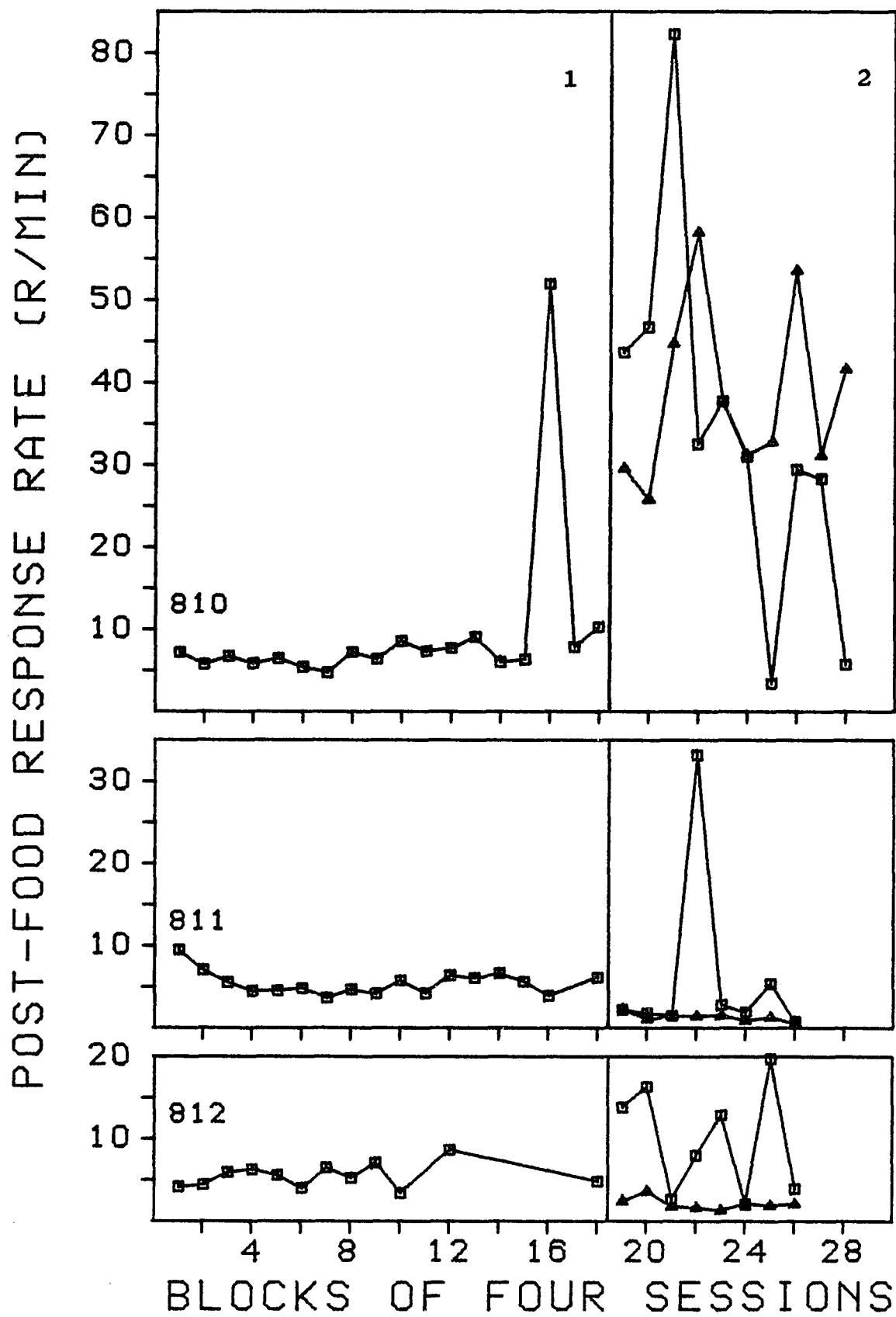
during Phase 3 proceeded at a slower rate than did acquisition of the original discrimination in Phase 1. In no case was either of the two DI's at the end of Phase 3 at the same level as had been present at the end of Phase 1.

Further data regarding lever-pressing are presented in Appendix A. A brief summary of those data is given here. The post-food discrimination between pre-food and pre-stimulus signals resulted uniformly from longer latencies and lower lever-press counts during pre-stimulus than during pre-food components. The diminished post-food discrimination of Phase 2 resulted from elimination of both the latency and response-count differences. Post-food latency differences were generally not recovered during Phase 3, while response-count differences did recover to some extent. The post-stimulus discrimination during Phase 1 was largely attributable to a higher response count during pre-food than during pre-stimulus components. Post-stimulus latency differences were much less consistent than were post-food latency differences in Phase 1. The difference in post-stimulus responses per component diminished during Phase 2, and recovered to some extent in Phase 3.

Among control subjects, average lever-press rates, latencies, and counts were similar to the averages for experimental animals. Response rates for the control subjects are presented in Figures 15 and 16. It should be recalled that these subjects were initially trained without signals for 75 sessions. Subjects 811 and 812 were

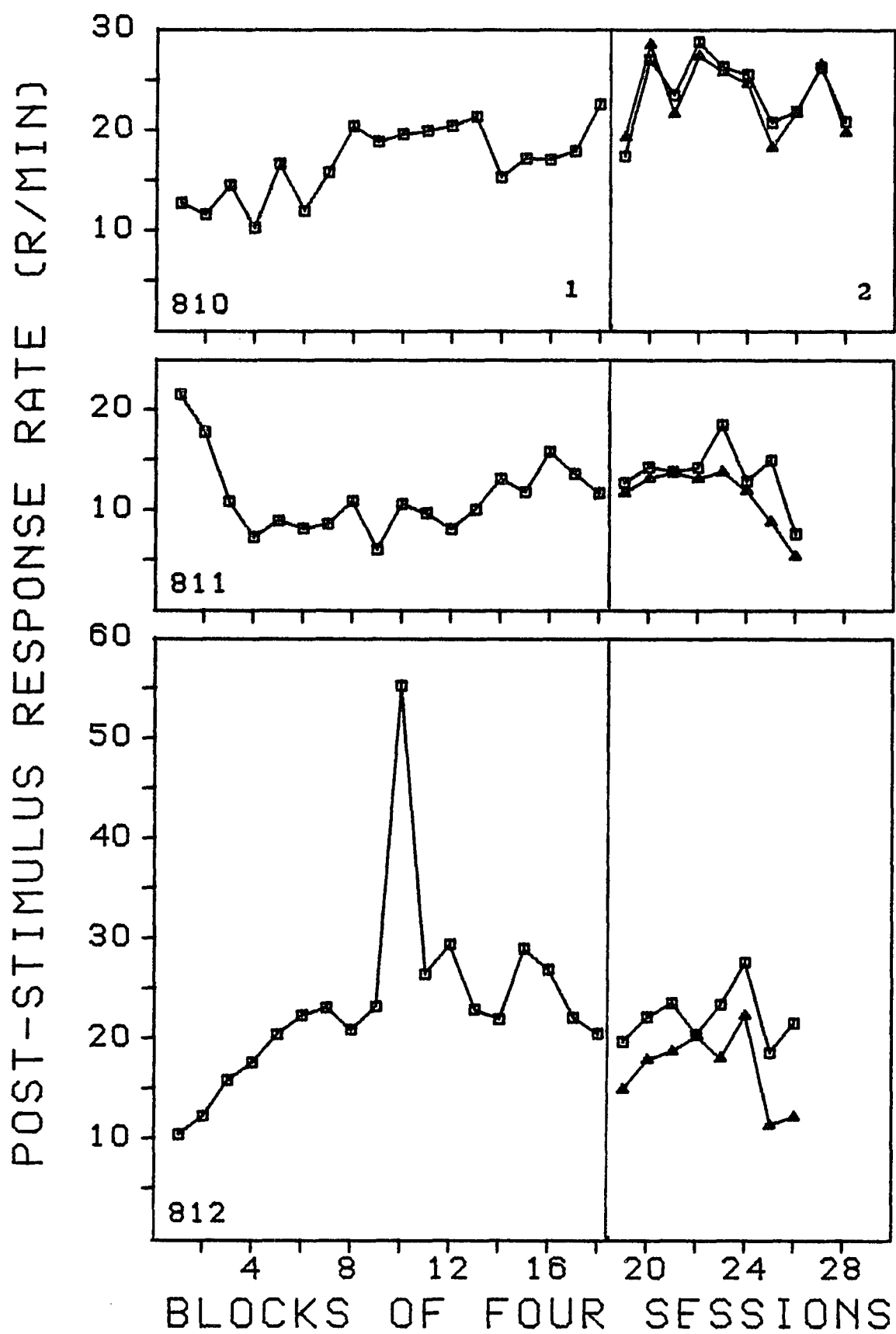
Post-Food Response Rates

Figure 15. Data represent running lever-press rates during post-food components, computed as described under General Methods, for the control subjects (810 - 812). Phases 1 and 2, identified by 1-digit numbers, are separated by a vertical line. Individual subjects are identified by means of 3-digit numbers. During Phase 1, when no signals were presented, squares represent post-food rates. During Phase 2, following the introduction of signals, squares represent pre-food (FF) behavior for Subjects 811 and 812, while triangles represent pre-stimulus (SF) behavior. For Subject 810 during Phase 2, squares represent behavior in the presence of the tone; triangles, behavior in the presence of the repetitive click. Neither tone nor click was correlated with component-outcomes for Subject 810 during Phase 2. Individual data points represent performance averaged over 4 consecutive sessions.



### Post-Stimulus Response Rates

Figure 16. Data represent running lever-press rates during post-stimulus components, computed as described under General Methods, for the control subjects (810 - 812). Phases 1 and 2, identified by 1-digit numbers, are separated by a vertical line. Individual subjects are identified by means of 3-digit numbers. During Phase 1, when no signals were presented, squares represent post-food rates. During Phase 2, following the introduction of signals, squares represent pre-food (FS) behavior for Subjects 811 and 812, while triangles represent pre-stimulus (SS) behavior. For Subject 810 during Phase 2, squares represent behavior in the presence of the tone; triangles, behavior in the presence of the repetitive click. Neither tone nor click was correlated with component-outcomes for Subject 810 during Phase 2. Individual data points represent performance averaged over 4 consecutive sessions.



thereafter presented with outcome-correlated signals; Subject 810, with outcome-uncorrelated signals. Subjects 811 and 812 both acquired a pre-food/pre-stimulus discrimination. Acquisition was somewhat faster than was acquisition of a reversed discrimination by subjects in the experimental group. For Subject 810, introduction of the signals led to marked fluctuations in post-food rates, but not in post-stimulus rates. In general, with the exception of the post-food rates of Subject 810, average response rates after introduction of the signals were comparable to those observed prior to introduction of the signals.

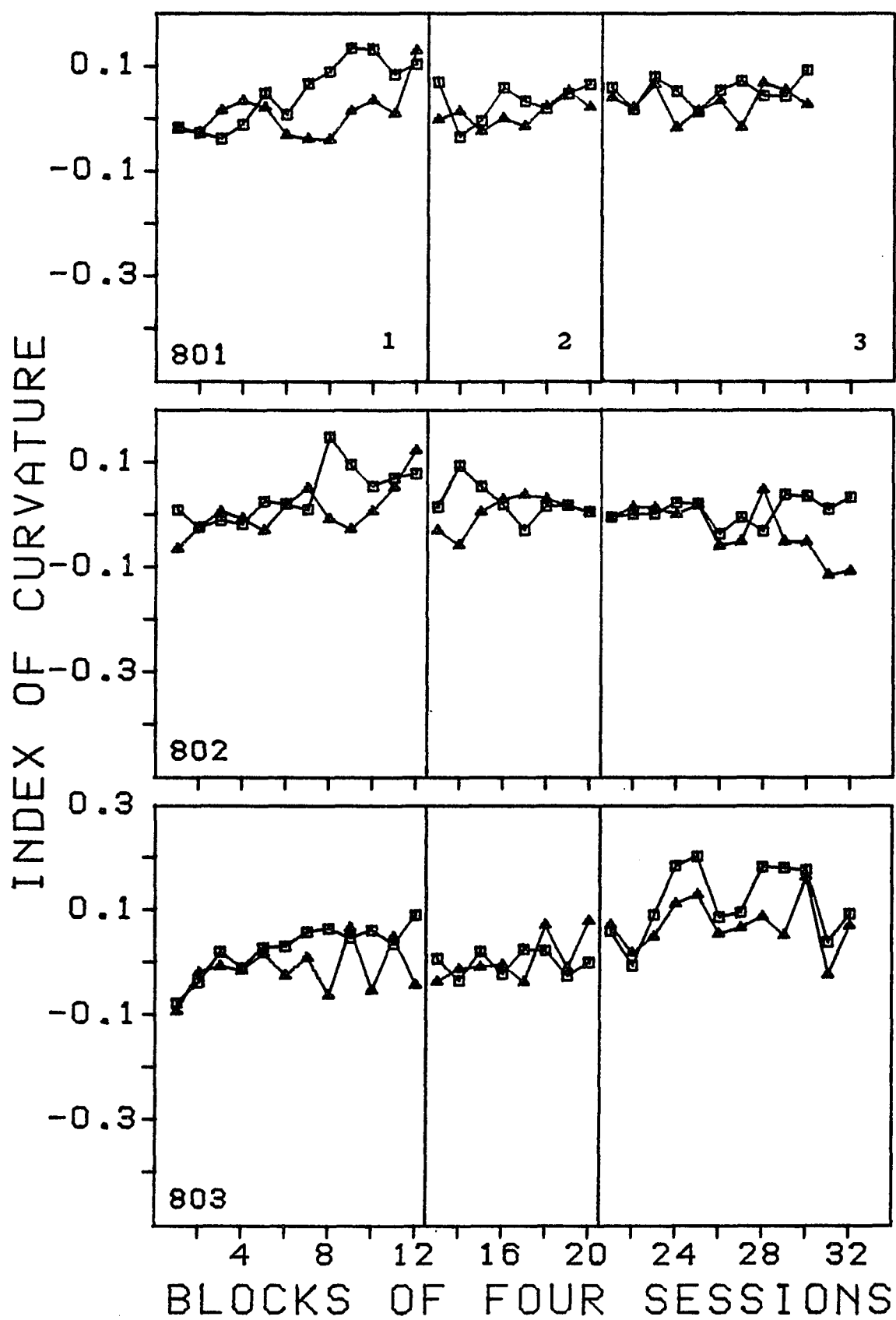
Reflection suggested a possible functional similarity between the pre-food signal of the present experiment and the food-paired stimulus of Experiment 3. This similarity, which will be discussed further in conjunction with Experiment 3, necessitated examinations of lick and lever-press distributions, and of lick latencies obtained in the present experiment. These results are included in this section.

Indices of curvature (IC's) for post-stimulus lever-pressing are presented in Figures 17 - 19. It can be seen that pre-food indices were generally more positive than were pre-stimulus indices at the end of Phase 1 among the experimental subjects. Pre-stimulus indices were generally close to 0 for these animals, as were the post-stimulus indices for the control animals. Animals, therefore, tended to distribute their lever-presses differently during

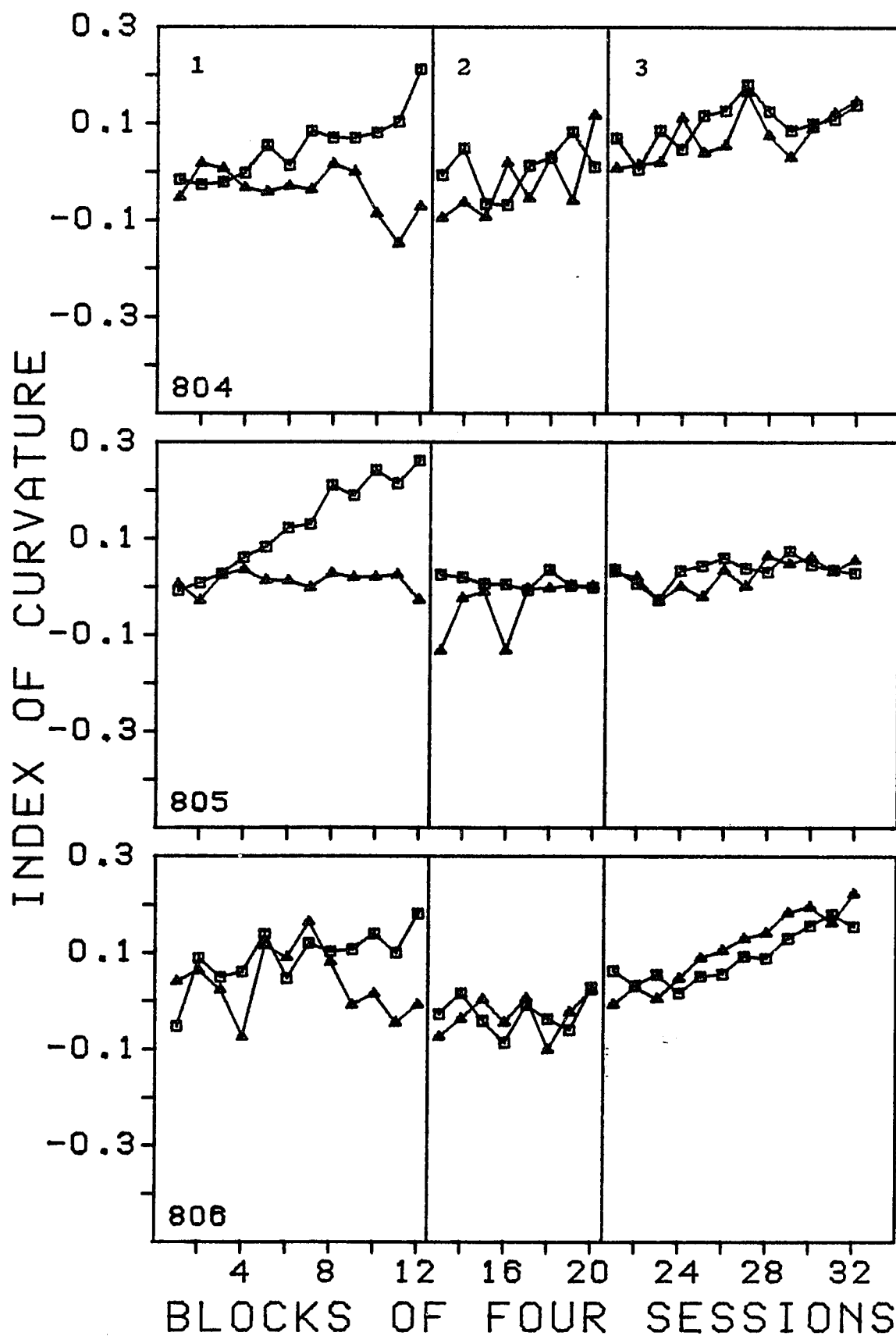
### Indices of Curvature:

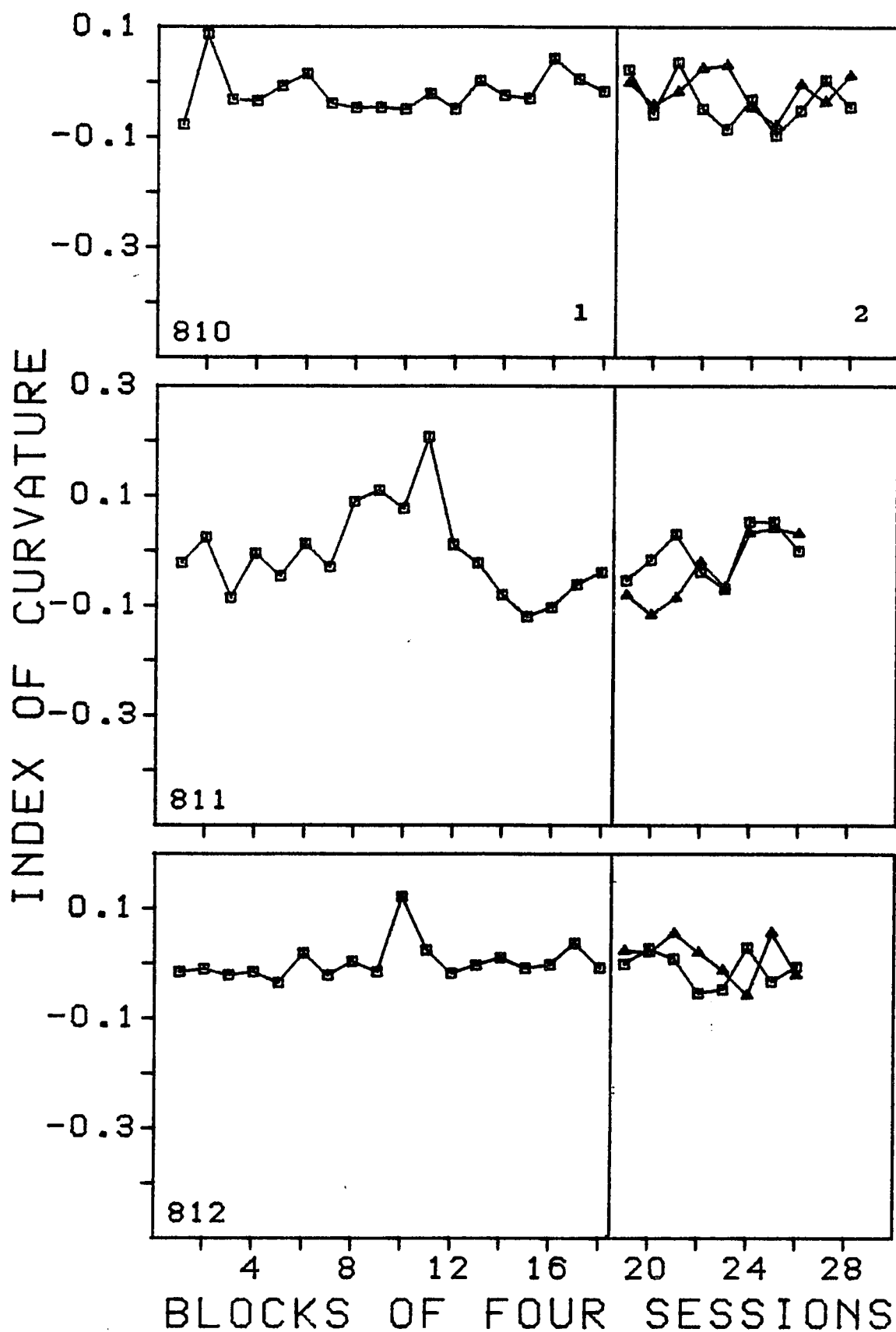
#### Post-Stimulus Lever-Pressing

Figures 17 - 19. Data represent indices of curvature, as described above under Method, for all subjects for which lever-pressing was required (801 - 806, 810 - 812). Phases of the experiment (1 - 3 for experimental subjects, 1 and 2 for control subjects) are identified by 1-digit numbers and separated by vertical lines. Individual subjects are identified by means of 3-digit numbers. For experimental subjects (801 - 806, Figures 17 and 18) during Phases 1 and 3, and for control subjects (811 and 812, Figure 19) during Phase 2, squares represent pre-food (FS) behavior, while triangles represent pre-stimulus (SS) behavior. For experimental subjects during Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. For Subject 810 during Phase 2, squares represent behavior in the presence of the tone; triangles, behavior in the presence of the repetitive click. For control subjects (810 - 812) during Phase 1, squares represent average post-stimulus behavior. Individual data points represent performance averaged over 4 consecutive sessions.









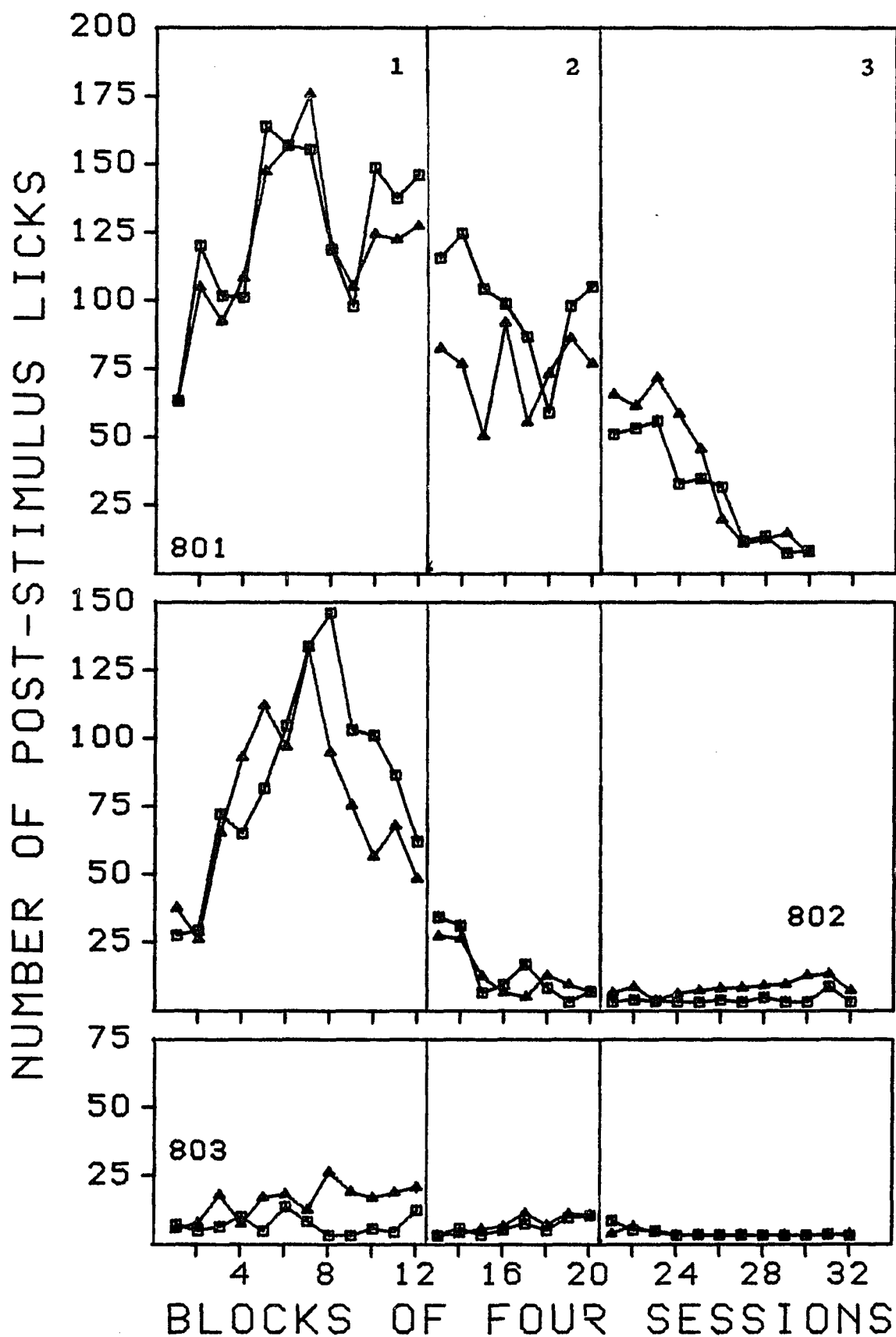
pre-food than during pre-stimulus components. Lever-pressing occurred at a lower rate early than it did late during pre-food components. Lever-pressing was maintained at a roughly constant rate within pre-stimulus components. Pre-food (FS) patterns were thus more similar to typical post-food patterns (Preliminary Research, Appendix A) than were pre-stimulus (SS) patterns. The pre-food pattern disappeared during Phase 2. Pre-stimulus patterns were unaffected by the transition from Phase 1 to Phase 2. In only 2 cases (802, 803) was there evidence that the pre-food/pre-stimulus difference in IC's which characterized performance at the end of Phase 1 was recaptured during Phase 3. In fact, for one subject (806), the pre-stimulus index was consistently more positive during Phase 3 than was the pre-food index.

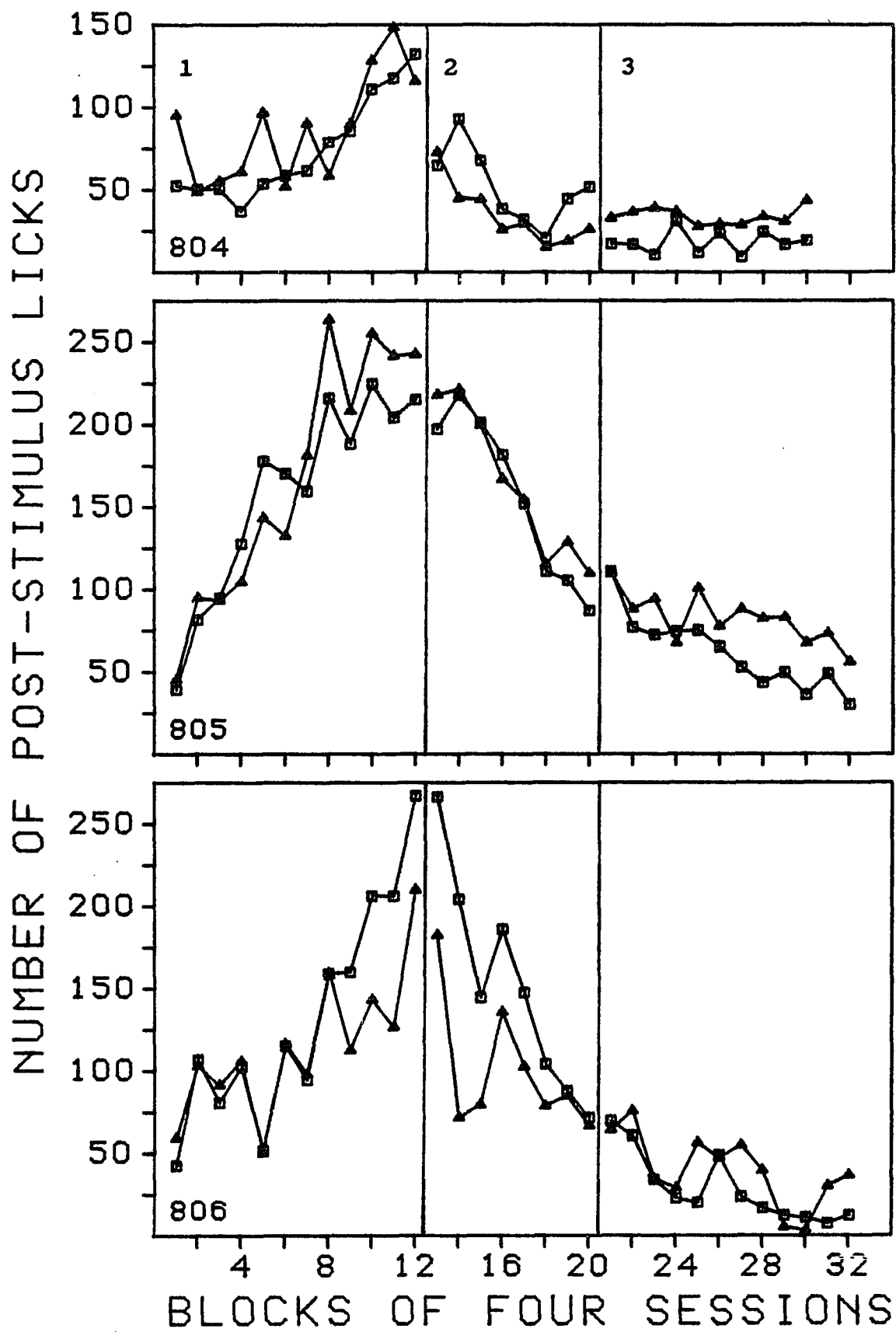
Pre-stimulus components were uniformly longer than pre-food components at the end of Phase 1. This was true of both post-food and post-stimulus components. The difference was eliminated during Phase 2, and had begun to emerge by the end of Phase 3 (see Appendix A). Mean component durations did not differ between post-food and post-stimulus components.

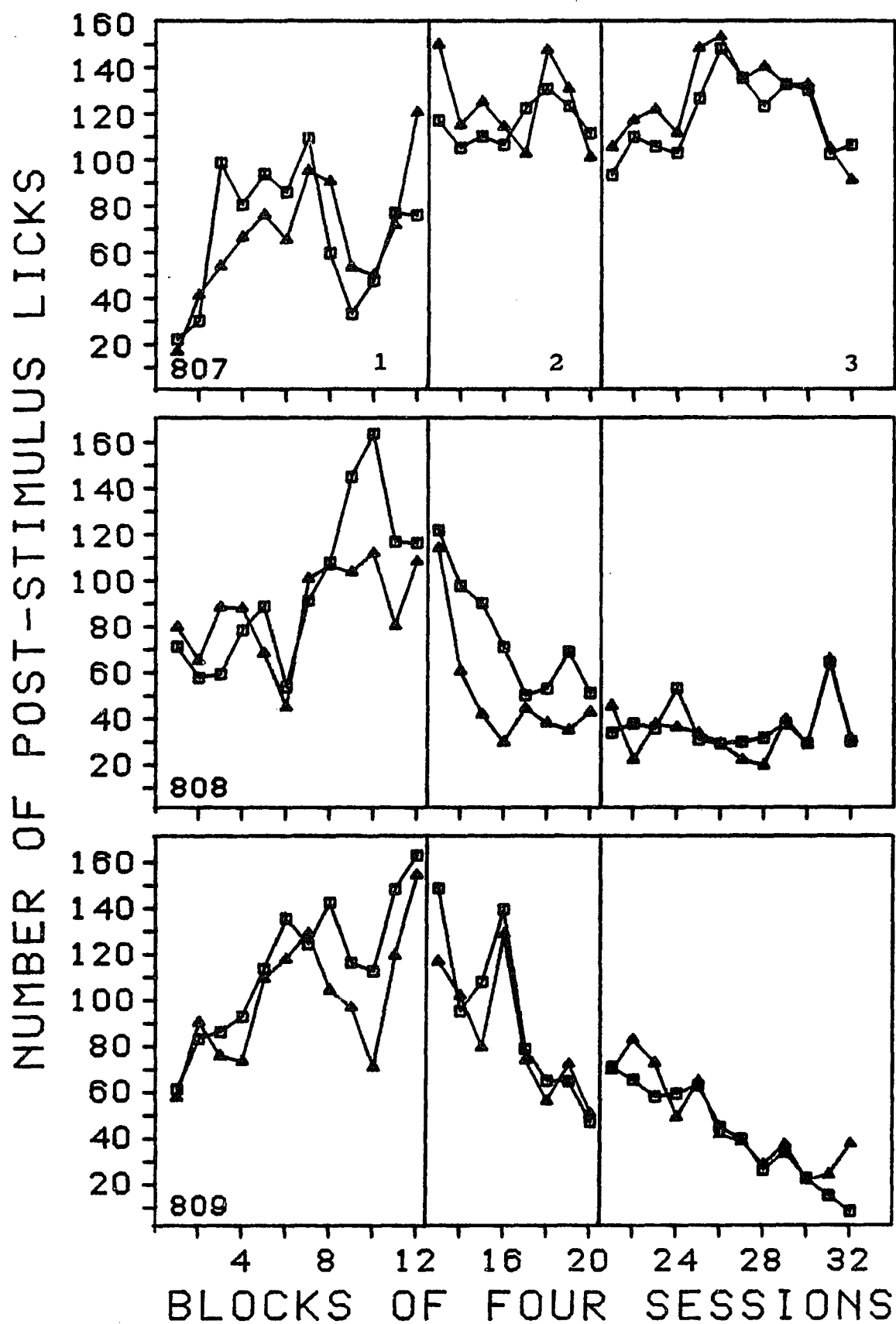
Post-stimulus drinking levels (licks per component) are presented in Figures 20 - 23. The plotted values were computed by dividing the total number of licks per session within a given component type by the total number of occurrences per session of that component type. The data

Post-Stimulus Drinking Levels

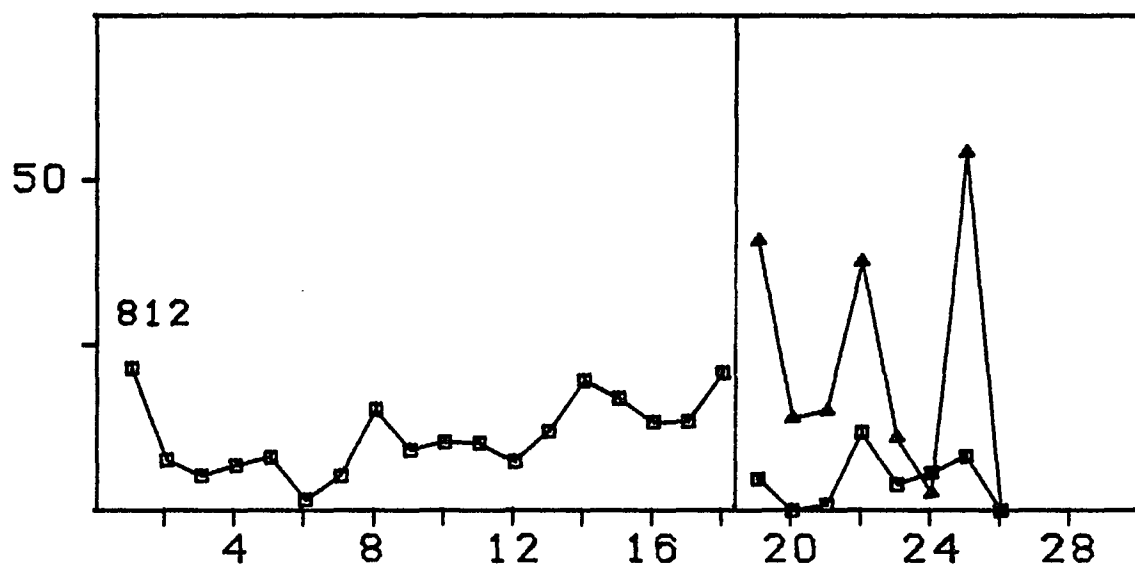
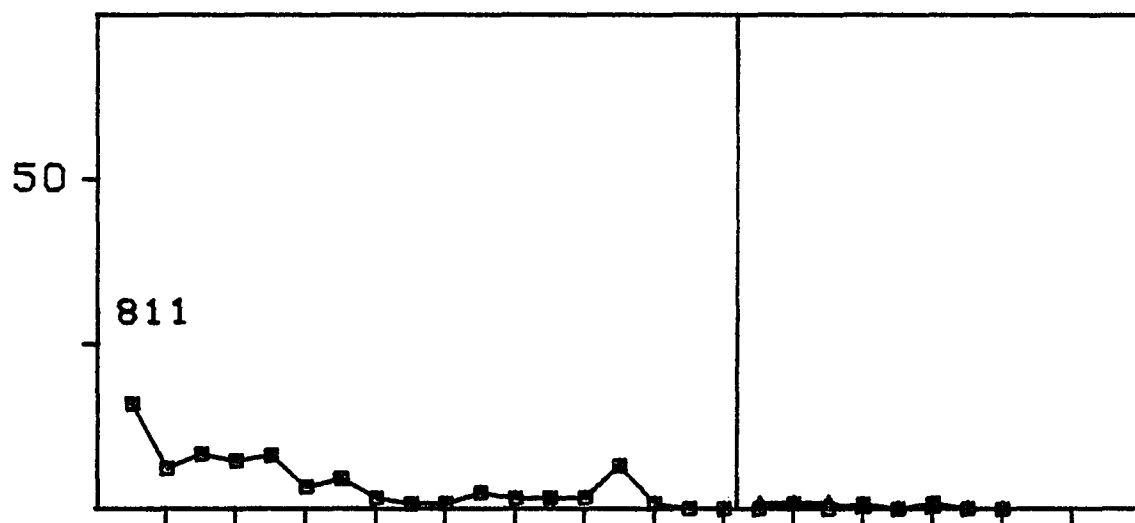
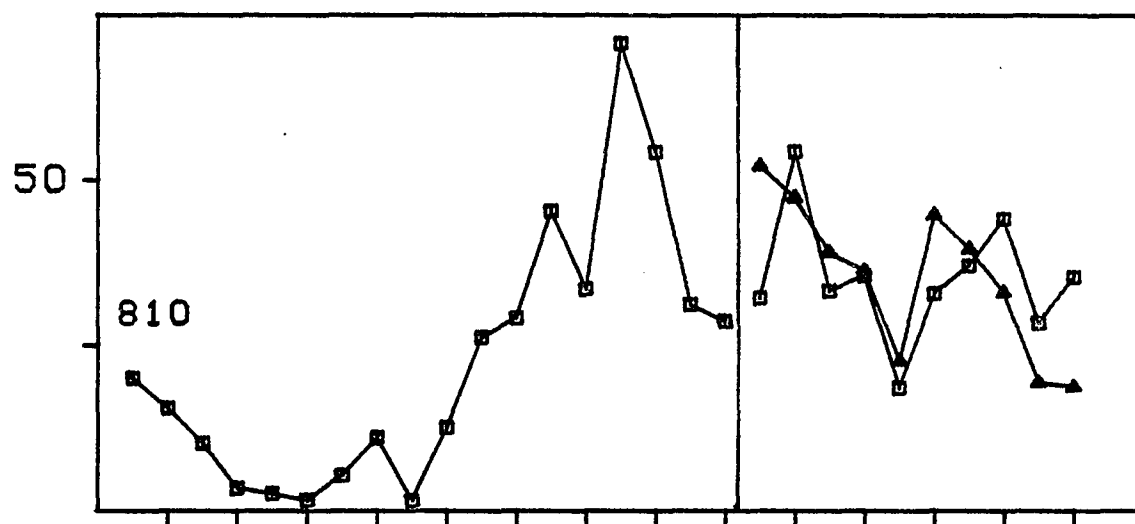
Figures 20 - 23. Data represent mean licks per post-stimulus component, calculated as described in the text. Phases of the experiment (1 - 3 for experimental subjects, 1 and 2 for control subjects) are identified by 1-digit numbers and separated by vertical lines. Individual subjects are identified by means of 3-digit numbers. For experimental subjects (801 - 809, Figures 20 - 22) during Phases 1 and 3, and for control subjects (811 and 812, Figure 23) during Phase 2, squares represent pre-food (FS) behavior, while triangles represent pre-stimulus (SS) behavior. For experimental subjects during Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. For Subject 810 during Phase 2, squares represent behavior in the presence of the tone; triangles, behavior in the presence of the repetitive click. For control subjects (810 - 812) during Phase 1, squares represent average post-stimulus behavior. Individual data points represent performance averaged over 4 consecutive sessions.







NUMBER OF POST-STIMULUS LICKS



BLOCKS OF FOUR SESSIONS



may thus be regarded as a composite of the proportion of components of a given type during which drinking actually occurred, and of the number of licks per component in which drinking actually occurred. The latter two aspects of the data, as well as post-food drinking levels, are presented in Appendix A.

Eight of the nine subjects presented with pre-food/pre-stimulus signals rapidly acquired post-stimulus drinking (Figures 20 - 22). It can be seen that post-stimulus drinking levels among animals in the response-independent condition (Subjects 807 - 809, Figure 22) were comparable to those for animals in the response-dependent condition (Figures 20 and 21).

By contrast, only 1 of 3 control subjects (810) exhibited substantial levels of post-stimulus drinking (Figure 23). The acquisition rate for that subject was much slower than those observed among the experimental subjects. In fact, post-stimulus drinking levels actually declined during early sessions for all control subjects. Subject #810 did not begin to drink during most post-stimulus components until after some 36 sessions of training. The lower levels of post-stimulus drinking seen with the control subjects were due both to the occurrence of drinking during a low proportion of post-stimulus components, and to fewer licks per component in which drinking actually occurred (Appendix A).

Among experimental animals, there were no consistent between-subjects differences between pre-food and pre-stimulus drinking levels. There were, however, some consistent within-subjects differences-- Subjects 801, 802, and 806 drank reliably more during pre-food than during pre-stimulus components; Subjects 803 and 805 consistently drank more during pre-stimulus components.

Phase 1 constituted the experiment as originally designed. Phases 2 and 3 were conducted for the following reasons. First, although the lever-pressing of the experimental animals reflected a consistent discrimination between pre-food and pre-stimulus signals (Figures 13 and 14), a similar discrimination with respect to drinking levels was not evidenced. Second, the likelihood and levels of post-stimulus drinking were higher among experimental than among control animals. The latter observation could have been due either to possible energizing effects on drinking of the signals (stimulus intensity dynamism), or to the predictability of component-outcomes as a result of the signal presentations. Since it was apparent that, at least at a gross level, drinking was not systematically related to the anticipation of food presentations, it seemed that a test of outcome predictability vs. stimulus-intensity effects might be of interest. Phase 2 of the experiment was conducted for that reason. In Phase 2, experimental animals continued to be presented with the same signals as were presented during Phase 1, but with the correlation between

those signals and component outcomes eliminated. If post-stimulus drinking were controlled by outcome predictability, this manipulation ought to lead to a decrement in post-stimulus drinking. If, however, post-stimulus drinking were influenced only by the stimulus effects of the signals, this manipulation ought to have no effect on drinking.

Returning again to a consideration of Figures 20 - 22, it can be seen that removal of the signal-outcome correlation of Phase 1 resulted in a clear decrement in levels of post-stimulus drinking for 7 of the 9 experimental animals. The post-stimulus drinking of Subject 807 was relatively unaffected by the transition to Phase 2; that of Subject 802 showed a consistent downward trend prior to the introduction of Phase 2. It would thus seem that outcome predictability, rather than possible effects of the auditory signals on arousal level, best explained the difference in drinking levels between the experimental and the control subjects.

Phase 3 was an attempt to recapture the post-stimulus drinking levels which were present at the end of Phase 1. Such a demonstration would have provided conclusive evidence that outcome predictability plays an important role in controlling post-stimulus drinking. The information content of the signals in Phase 3 was reversed from that of Phase 1. Thus, subjects presented with signal pair S1 (Table 3) during Phase 1 were presented with pair S2 in Phase 3. The

reversal was instituted because animals presented with signal pair S2 during Phase 1 seemed to drink more reliably during post-stimulus components and to have been less disturbed by the transition from Phase 1 to Phase 2. It can be seen from Figures 20 - 22 that the drinking levels of Phase 1 were not recaptured during Phase 2.

Among control subjects (Figure 23), drinking levels following the introduction of signals were, on average, not different from those exhibited in the absence of signals.

Levels of post-food drinking (Appendix A) were generally not sensitive to changes in experimental conditions.

Three measures of drinking, level (licks per component), bout duration, and bout rate, were subjected to multiple regression analyses. Data from all 12 subjects were used in initial analyses of drinking level and of bout duration. Only data from experimental subjects in the response-dependent condition (801 - 806) were used in the analysis of bout rates and in re-analyses of drinking levels and bout durations (see below). Dependent measures for experimental subjects represented performance at the conclusions of Phases 1 and 2: behavior was averaged over sessions 45 - 48 and over sessions 77 - 80. Phase 3 behavior was not included because Phase 3 drinking did not differ markedly between Phases 2 and 3 (Figures 20 - 22). Behavior of control subjects, averaged over sessions 45 - 48 and over sessions 68 - 71 was included in the initial

analyses of drinking levels and of bout durations.

The following contrasts were used in initial analyses of drinking levels and bout durations: average pre-food vs. average pre-stimulus behavior (Subjects 801 - 809, Phase 1); average post-food behavior vs. average post-stimulus behavior (Subjects 801 - 812; Phases 1 and 2); average pre-response vs. average post-response behavior (Subjects 801 - 806, 810 - 812, Phases 1 and 2, Phases 1 and 2); average behavior of subjects for which lever-pressing was required (801 - 806, 810 - 812, Phases 1 and 2) vs. that of subjects for which lever-pressing was not required (807 - 809, Phases 1 and 2); and average behavior of subjects presented with signal pair S1 (Table 2) during Phase 1 (801 - 803, 808, 809, Phases 1 and 2) vs. that of subjects presented with pair S2 during Phase 1 (804 - 807, Phases 1 and 2). Finally, behavior of control subjects was pooled with the Phase 2 behavior of experimental subjects and contrasted with the Phase 1 behavior of experimental subjects as a test of the effect of outcome predictability. Results of the analyses are presented in Table 5, for drinking levels, and in Table 6, for bout durations.

With respect to drinking levels (Table 5), the only contrast which did not yield a statistically significant difference was that between pre-food and pre-stimulus behavior, thereby confirming the apparent lack of a difference seen in Figures 20 - 22. Drinking levels were higher when component outcomes were predictable than when

### Analyses of Effects on Licking

Tables 5 and 6. Effects of a variety of factors on 2 measures of drinking were analyzed by means of Multiple Regression Analysis. Licks per component and bout durations, averaged over sessions 45 - 48 and over sessions 77 - 80 for experimental subjects (801 - 809), and over sessions 45 - 48 and over sessions 69 - 72 for the control subjects (810 - 812) comprised the dependent measures. The data thus represented performance at the conclusions of Phases 1 and 2 for the experimental subjects, and performance after equivalent amounts of experience for the control subjects. The principle results are summarized in Figure 5 for licks per component, and in Figure 6 for bout durations.

### Notes

1. The vectors used in the analyses made the following comparisons: A-- behavior during signalled pre-food components vs. behavior during signalled pre-stimulus components; B-- behavior during post-food components vs. behavior during post-stimulus components; C-- behavior prior to the onset of lever-pressing vs. behavior subsequent to the onset of lever-pressing; D-- behavior while component outcomes were predictable vs. behavior while outcomes were unpredictable; E-- behavior among subjects for which lever-pressing was required vs. behavior among subjects for which lever-pressing was not required; and F-- behavior among subjects presented with signal pair S1 (801 - 803, 808 - 809) vs. behavior among subjects presented with signal pair S2 (804 - 807).

2. Several interactions included in the analyses are not presented in the tables because their effects did not approach significance: A x B, A x C, A x E, A x F, C x D, D x F, A x B x C, A x B x C x D x F. Degrees of freedom for those interactions are not included in the residual degrees of freedom.

Table 5.

Multiple Regression Analysis: Licks per Comment.

Source (1)	df	SS	MS	F	r-Squared
A. Pre F/S	1	66	66	0.1	0.00003
B. Post F/S	1	590208	590208	492.7**	0.26
C. Pre/Post R	1	492416	492416	411.0**	0.21
D. Predict	1	42694	42694	35.6**	0.02
E. Resp. Req.	1	138130	138130	115.3**	0.06
F. Sig. Pair	1	7493	7493	6.3*	0.003
Interactions					
B x C	1	866490	866490	721.5**	0.37
B x D	1	10640	10640	8.9**	0.005
C x F	1	6920	6920	5.8*	0.003
Residual (2)	124	148964	1201		
Total	143	2311704			0.94

\*-- p < 0.05  
 \*\*-- p < 0.01

Table 6Multiple Regression Analysis: Bout Duration

Source (1)	df	SS	MS	F	r-Squared
A. Pre F/S	1	1179	1179	0.8	0.001
B. Post F/S	1	197062	197062	139.0**	0.21
C. Pre/Post R	1	256780	256780	181.1**	0.27
D. Predict	1	5567	5567	3.9	0.01
E. Resp. Req.	1	8200	8200	5.8*	0.01
F. Sig. Pair	1	679	679	0.5	0.0007
Interactions					
B x C	1	245617	245617	173.2**	0.26
B x D	1	11253	11253	7.9**	0.01
C x F	1	22067	22067	15.6**	0.02
Residual (2)	124	178730	1418		
Total	143	939625			0.81

\*-- p &lt; 0.05

\*\*-- p &lt; 0.01



they were unpredictable, confirming the visual impression conveyed by Figures 20 - 23. The finding of a significant effect of the lever-press requirement, such that drinking levels were higher when lever-pressing was not required, is largely attributable to the low levels of post-stimulus drinking among control subjects. Among the experimental animals, drinking levels were higher among those presented with signal pair S2 during Phase 1 than among those presented with pair S1, thereby justifying the reversal of signals during Phase 3. Average post-food levels greatly exceeded average post-stimulus levels, and average pre-response levels greatly exceeded average post-response levels.

Several interactions were included in the analysis. Three were statistically significant. The B x C interaction indicates that F1 levels greatly exceeded F2, S1, and S2 levels. This will be borne out by a re-analysis of the data (Tables 8 and 9). The B x D interaction resulted from a greater decrement in post-stimulus than in post-food drinking when components were unpredictable. The C x F interaction resulted, again, from generally higher levels of drinking among subjects originally presented with signal pair S2 than among those presented with pair S1. A re-analysis of drinking levels will be presented in Table 7.

With respect to bout durations (Table 6), average durations were lower among subjects for which lever-pressing was not required than among those for which it was required.

As with drinking levels, average post-food bout durations exceeded average post-stimulus durations, and average pre-response bout durations exceeded average post-response bout durations. The interactions described above were significant. The B x D interaction indicates that average post-stimulus bout durations suffered a greater decrement than did average post-food durations when component outcomes were made unpredictable. The C x F interaction was largely attributable to longer average bout durations among subjects originally presented with signal pair S2 than among those originally presented with pair S1. The E x C interaction reflected a much greater average duration for F1 bouts than for F2, S1, or S2 bouts. A re-analysis of the bout duration data is presented in Table 9.

Drinking levels and bout durations were re-analyzed to take into account the rather large difference between the F1 and other categories of drinking. The post-food/post-stimulus and pre-response/post-response vectors, and the vector which represented their interaction, were replaced by a set of vectors representing contrasts among the various categories of drinking. The first of these contrasted F2 with S2 drinking; the second contrasted S1 drinking with the average of F2 and S2 drinking; the third contrasted F1 drinking with the average of F2, S1, and S2 drinking. Other contrasts included in the analyses were: pre-food vs. pre-stimulus behavior, outcome predictability, and behavior among subjects originally presented with signal

### Re-Analyses of Effects on Licking

Tables 7 and 8. Effects on licking were re-analyzed, using a modified set of contrast vectors, by means of Multiple Regression Analysis. Licks per component and bout durations, averaged over sessions 45 - 48 and over sessions 77 - 80 for experimental subjects (801 - 806), comprised the dependent measures. The data thus represented performance at the conclusions of Phases 1 and 2. The principle results are summarized in Figure 7, for licks per component, and in Figure 8, for bout durations.

#### Note

1. The vectors used in the analyses made the following comparisons: A-- behavior during pre-food components vs. behavior during pre-stimulus components; B-- behavior while component outcomes were predictable vs. behavior while component outcomes were unpredictable; C-- behavior among subjects presented with signal pair S1 during Phase 1 vs. behavior among subjects presented with pair S2 during Phase 1; D-- S2 vs. F2 drinking; E-- S1 drinking vs. the average of S2 and F2 drinking; F-- F1 drinking vs. the average of S1, S2, and F2 drinking.

Table 7

Multiple Regression Analysis: Licks per Component

Source (1)	df	SS	MS	F	r-Squared
A. Pre F/S	1	14	14	0.01	0.000009
B. Predict	1	21811	21811	20.9**	0.01
C. Sig. Pair	1	10148	10148	9.7**	0.01
D. S2-F2	1	36355	36355	34.8**	0.02
E. S1-S2, F2	1	9104	9104	8.7**	0.01
F. F1-F2, S1, 2	1	1337566	1337566	1281.9**	0.87
Interactions					
A x F	1	2040	2040	2.0	0.001
B x C	1	4442	4442	4.3*	0.003
B x D	1	6936	6936	6.6*	0.005
C x D	1	6188	6188	5.9*	0.004
C x F	1	8613	8613	8.3**	0.01
Residual	84	87662	1044		
Total	95	1530879			0.94

\*-- p &lt; 0.05

\*\*-- p &lt; 0.01

Table 8

Multiple Regression Analysis: Bout Duration

Source (1)	df	SS	MS	F	r-Squared
A. Pre F/S	1	1989	1989	2.6	0.003
B. Predict	1	6033	6033	7.8**	0.01
C. Sig. Pair	1	1811	1811	2.3	0.003
D. S2-F2	1	5334	5334	6.9*	0.01
E. S1-S2, F2	1	1179	1179	1.5	0.002
F. F1-F2, S1, 2	1	478813	478813	615.5**	0.73
Interactions					
A x D	1	876	876	1.1	0.001
A x E	1	7792	7792	10.0**	0.01
B x C	1	765	765	1.0	0.001
B x D	1	1121	1121	1.4	0.002
B x E	1	3461	3461	4.5*	0.01
B x F	1	4457	4457	5.7*	0.01
C x F	1	75369	75369	96.9**	0.12
Residual	82	63787	778		
Total	95	652787			0.90

\*-- p < 0.05  
 \*\*-- p < 0.01

pair S1 vs. that of subjects originally presented with pair S2. Only data from subjects in the response-dependent experimental condition (801 - 806) were included in the analyses. The results of the analyses are presented in Table 7, for drinking levels, and in Table 8, for bout durations.

With respect to drinking levels (Table 7, see also Figures 24 - 27), F1 levels clearly exceeded the mean of F2, S1, and S2 levels. The mean of F2 and S2 levels exceeded S1 levels, largely as a result of high S2 levels. S2 levels exceeded F2 levels. Drinking levels were higher when outcomes were predictable than when they were unpredictable, and were higher among subjects originally presented with signal pair S2 than among those originally presented with pair S1 (Figures 20 and 21). The B x C interaction resulted primarily from a greater decrement in post-stimulus levels, when outcomes were made unpredictable, among subjects originally presented with signal pair S2 than among those originally presented with pair S1. The B x D interaction reflects a greater decline in S2 than in F2 levels when outcomes were made unpredictable. (F2 levels were, of course, relatively low while outcomes were predictable-- Figures 26 and 27.) The C x D interaction was due to greater S2 levels among subjects originally presented with signal pair S2 than among those originally presented with pair S1. The C x F interaction reflects greater short-bout (mean F2, S1, and S2) levels among subjects originally presented with

signal pair S2 than among those originally presented with pair S1.

Post-stimulus drinking levels for experimental subjects in the response-dependent condition (Subjects 801 - 806), broken down by pre-response (FS1, SS1) and post-response (FS2, SS2), are presented in Figures 24 and 25. As suggested by the above analysis, there were no reliable pre-food/pre-stimulus differences. FS2 levels were higher than SS2 levels for only 2 subjects at the end of Phase 1; the reverse was true in 3 cases. There were only 3 cases in which FS1 levels were higher than SS1 levels; there were, however, no cases in which SS1 levels were consistently higher than FS1 levels. Introduction of Phase 2 disrupted all categories of post-stimulus drinking. Phase 1 levels were not recaptured during Phase 3.

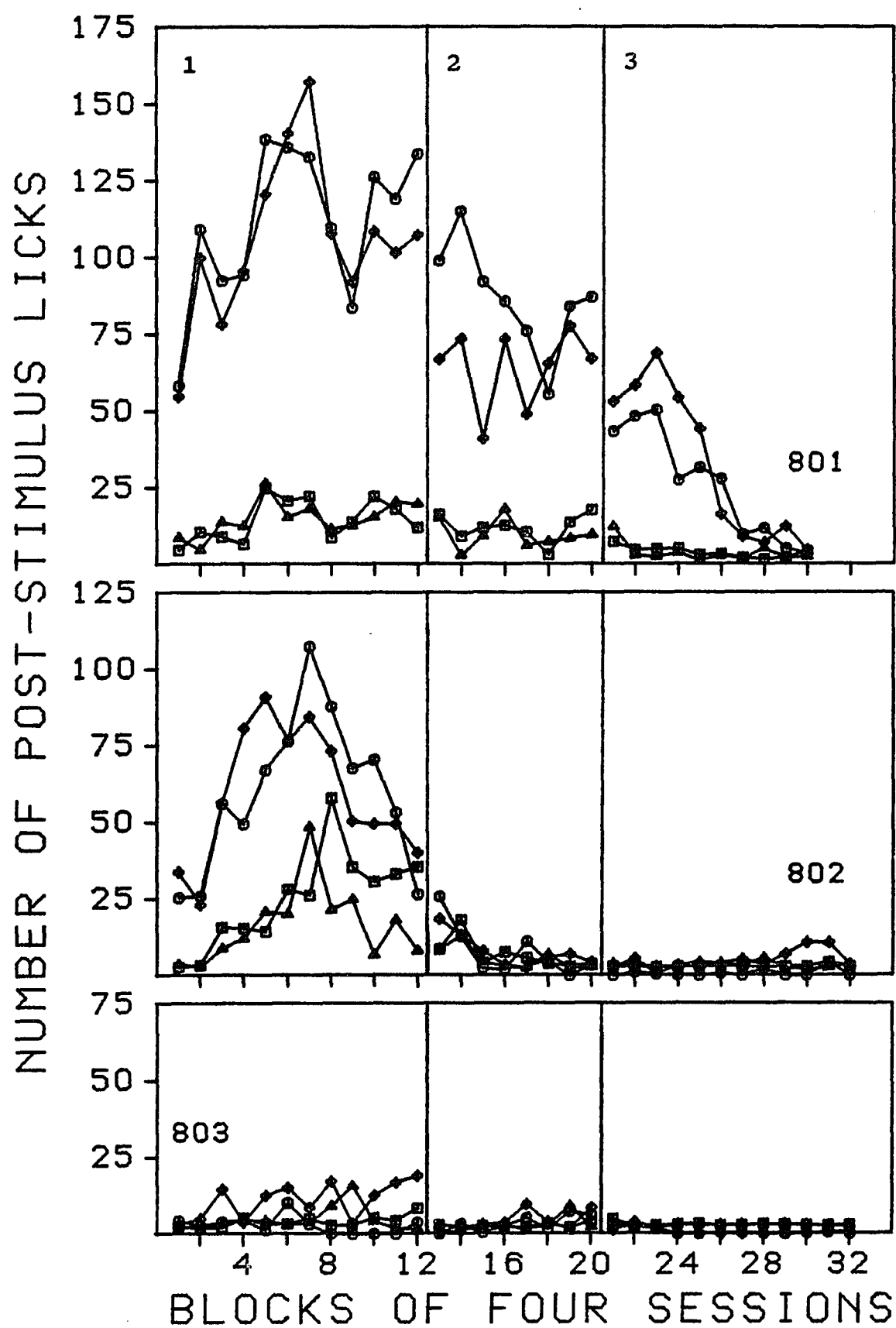
Post-food drinking levels, broken down by pre-response (FF1, SF1) and post-response (FF2, SF2) are presented in Figures 26 and 27. In 3 cases, FF2 levels consistently exceeded SF2 levels at the end of Phase 1. There were no cases in which the reverse was true. SF1 levels were consistently higher than FF1 levels at the end of Phase 1, an effect not captured in the MRA. That difference disappeared during Phase 2 and did not re-appear during Phase 3.

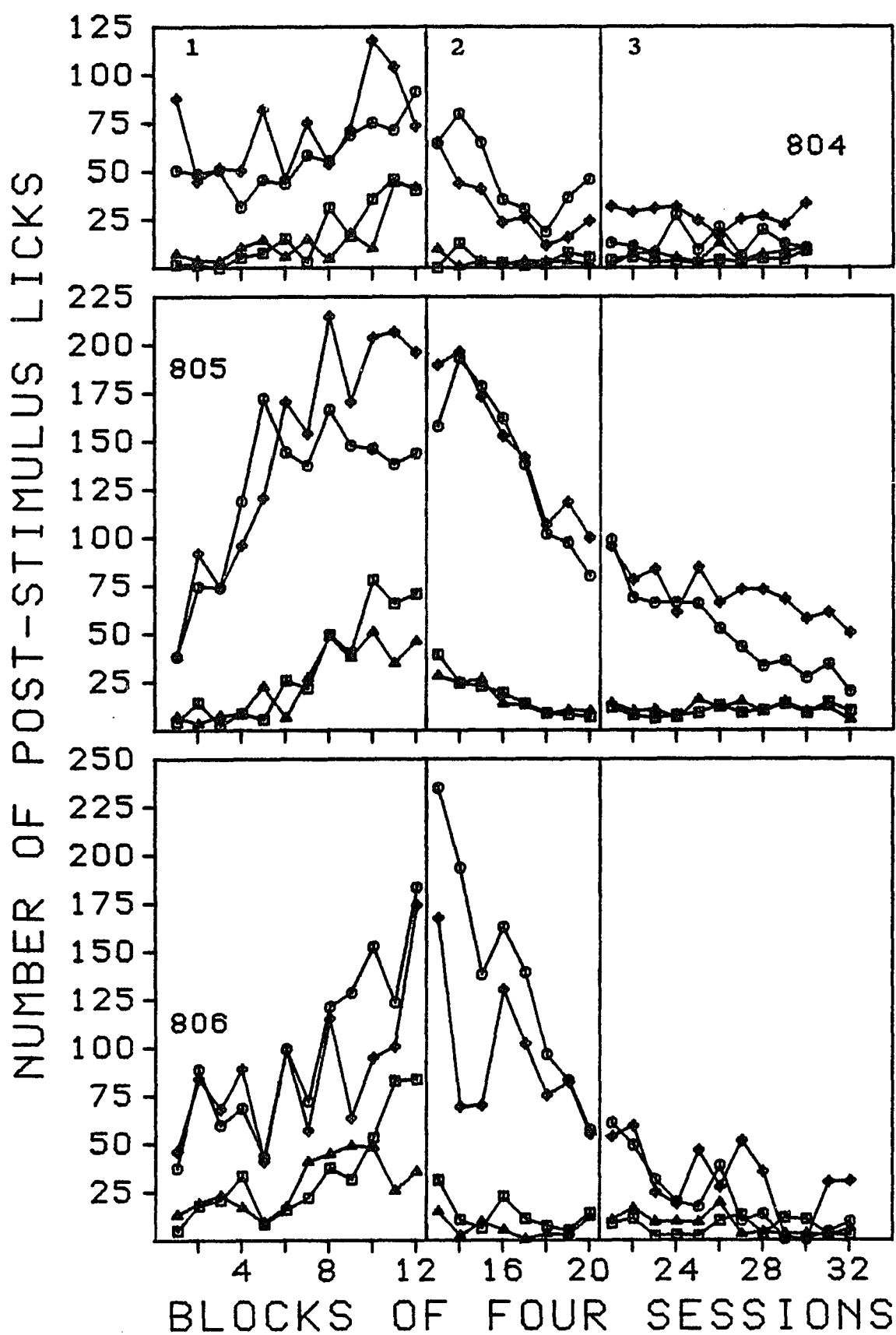
Post-Stimulus Drinking Levels:

Pre- and Post-Response

Figures 24 and 25. Data represent mean number of licks per post-stimulus component for the 6 experimental subjects in the response-dependent condition (801 - 806), broken down according to whether they occurred before (pre-response) or after (post-response) the onset of lever-pressing. Phases of the experiment are identified by 1-digit numbers, and are separated by vertical lines. Individual subjects are identified by means of 3-digit numbers. During Phases 1 and 3, the correspondence between symbols and lick categories (Table 2) is as follows: squares-- FS1; circles-- FS2; triangles-- SS1; and diamonds-- SS2. During Phase 2, squares and circles represent pre- and post-response drinking in the presence of the signal previously correlated with food presentations; triangles and diamonds, pre- and post-response drinking in the presence of the signal previously correlated with stimulus presentations. Individual data points represent behavior averaged over 4 consecutive sessions.



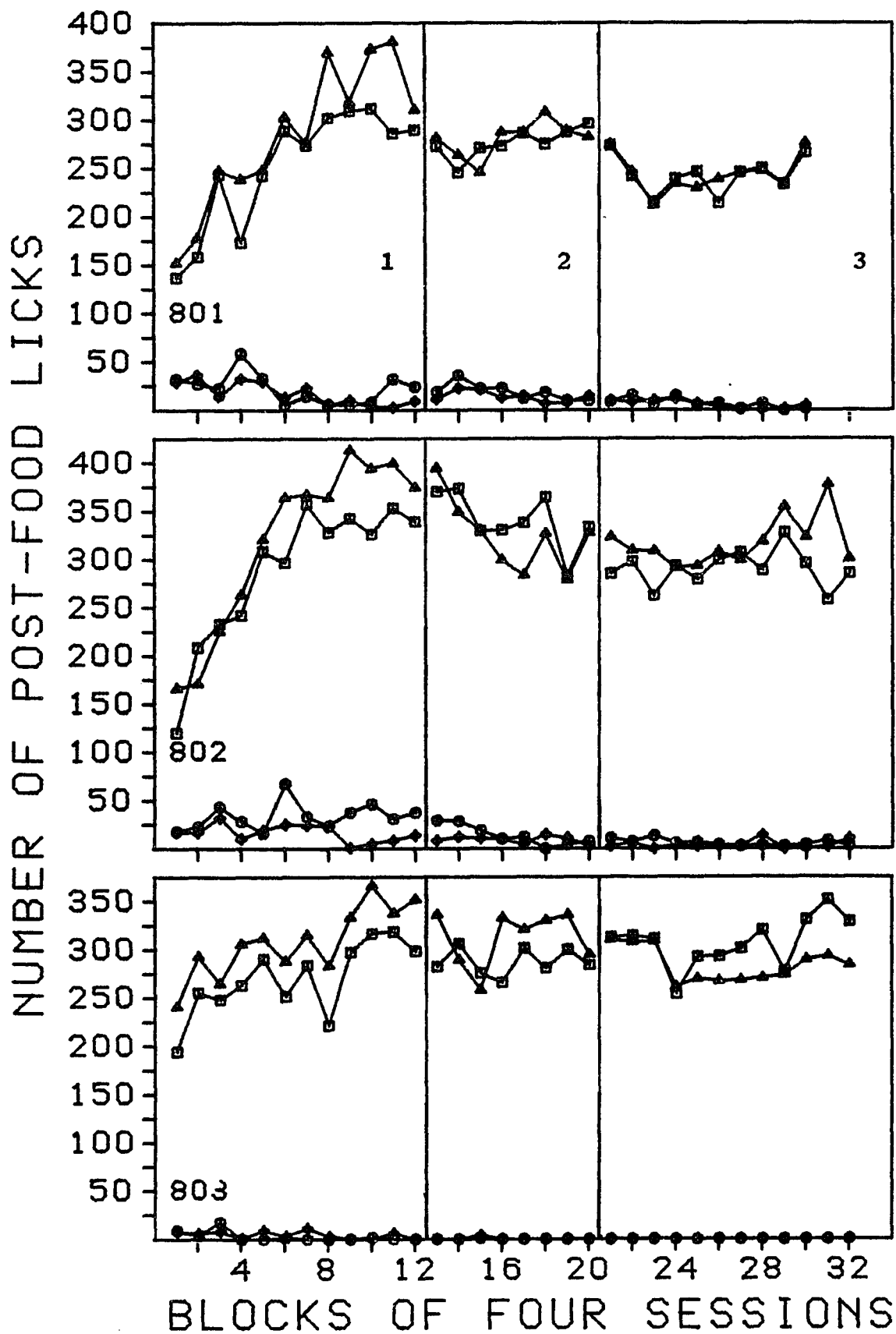


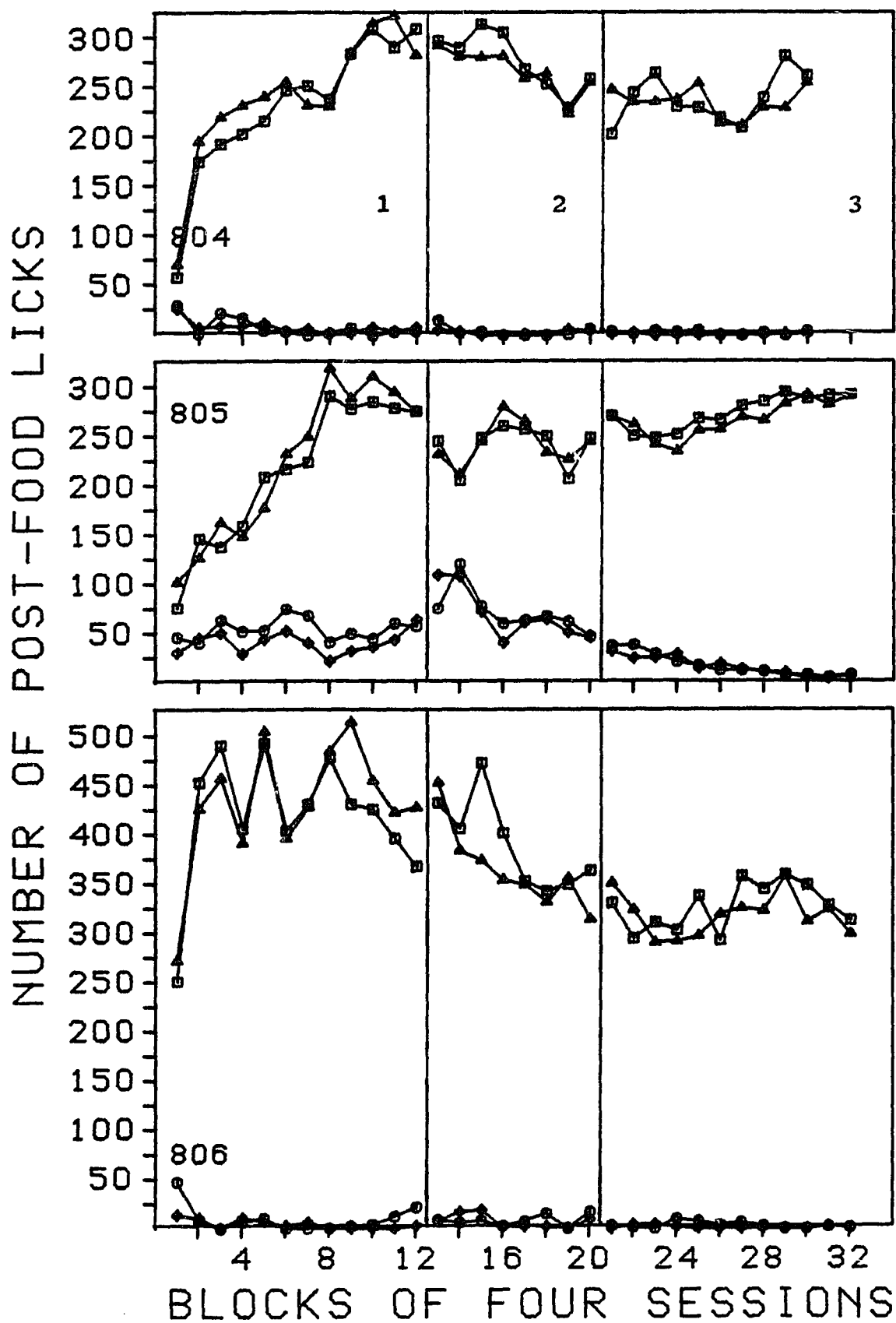


Post-Food Drinking Levels:

Pre- and Post-Response

Figures 26 and 27. Data represent mean number of licks per post-food component for the 6 experimental subjects in the response-dependent condition (801 - 806), broken down according to whether they occurred before (pre-response) or after (post-response) the onset of lever-pressing. Individual subjects are identified by 3-digit numbers. Phases of the experiment are identified by 1-digit numbers, and are separated by vertical lines. During Phases 1 and 3, the correspondence between symbols and lick categories (Table 2) is as follows: squares-- FF1; circles-- FF2; triangles-- SF1; and diamonds-- SF2. During Phase 2, squares and circles represent pre- and post-response drinking in the presence of the signal previously correlated with food presentations; triangles and diamonds, pre- and post-response drinking in the presence of the signal previously correlated with stimulus presentations. Individual data points represent behavior averaged over 4 consecutive sessions.



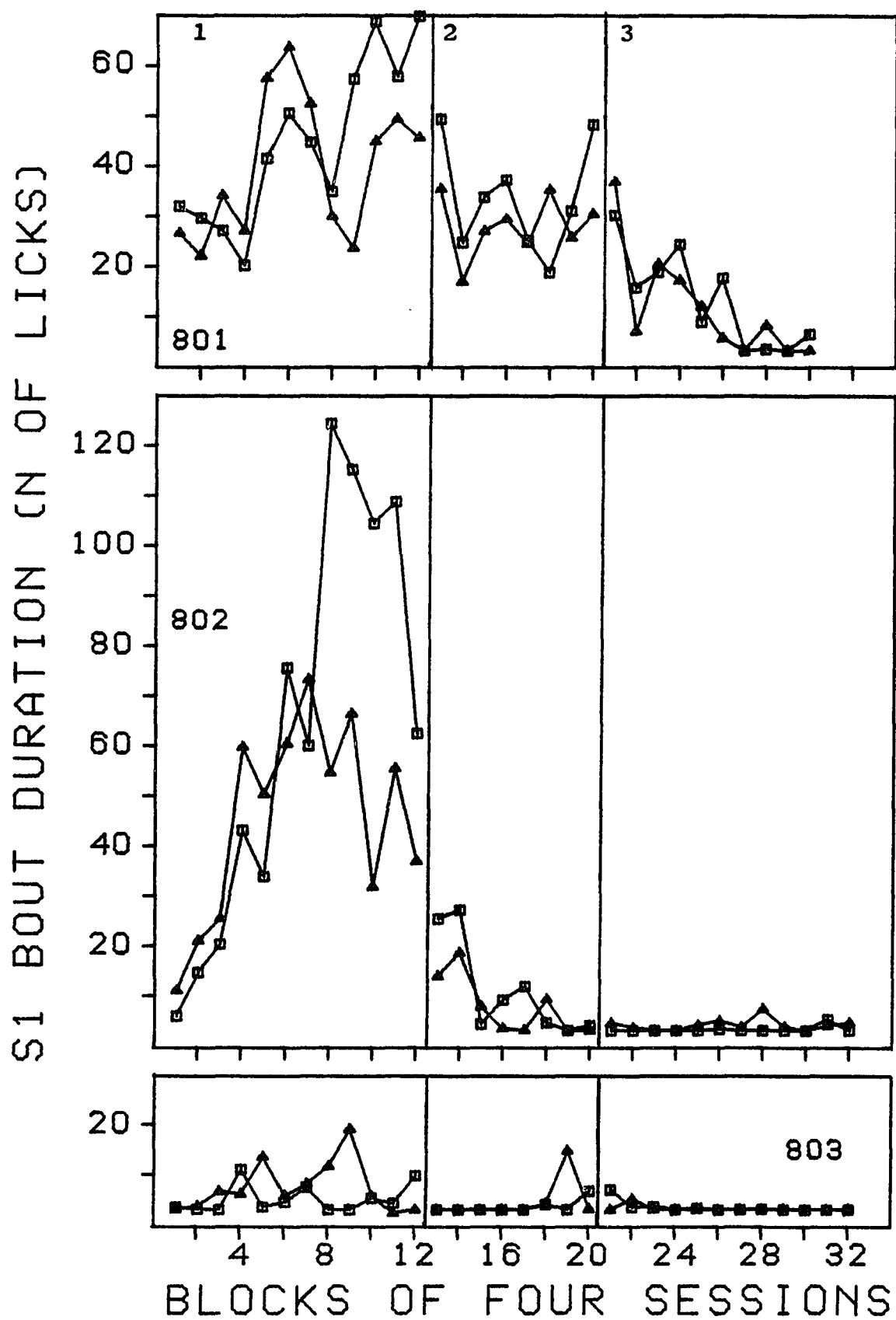


Results of the re-analysis of bout durations are presented in Table 8 (see also Figures 28 - 35). F1 bout durations greatly exceeded averaged F2, S1, and S2 bout durations. S2 durations exceeded F2 durations, but S1 durations did not differ from the average of F2 and S2 durations. Average bout durations were longer when component outcomes were predictable than when they were unpredictable. The A x E interaction was due to longer S1 bout durations during pre-food than during pre-stimulus components. The B x E interaction reflects the loss of that difference when outcomes were made unpredictable. The B x F interaction was due to a smaller decline in F1 bout durations than in averaged F2, S1, and S2 durations when component outcomes were made unpredictable. The C x F interaction indicates that F1 bout durations were longer among subjects presented with signal pair S1 during Phase 1 than among subjects originally presented with pair S2.

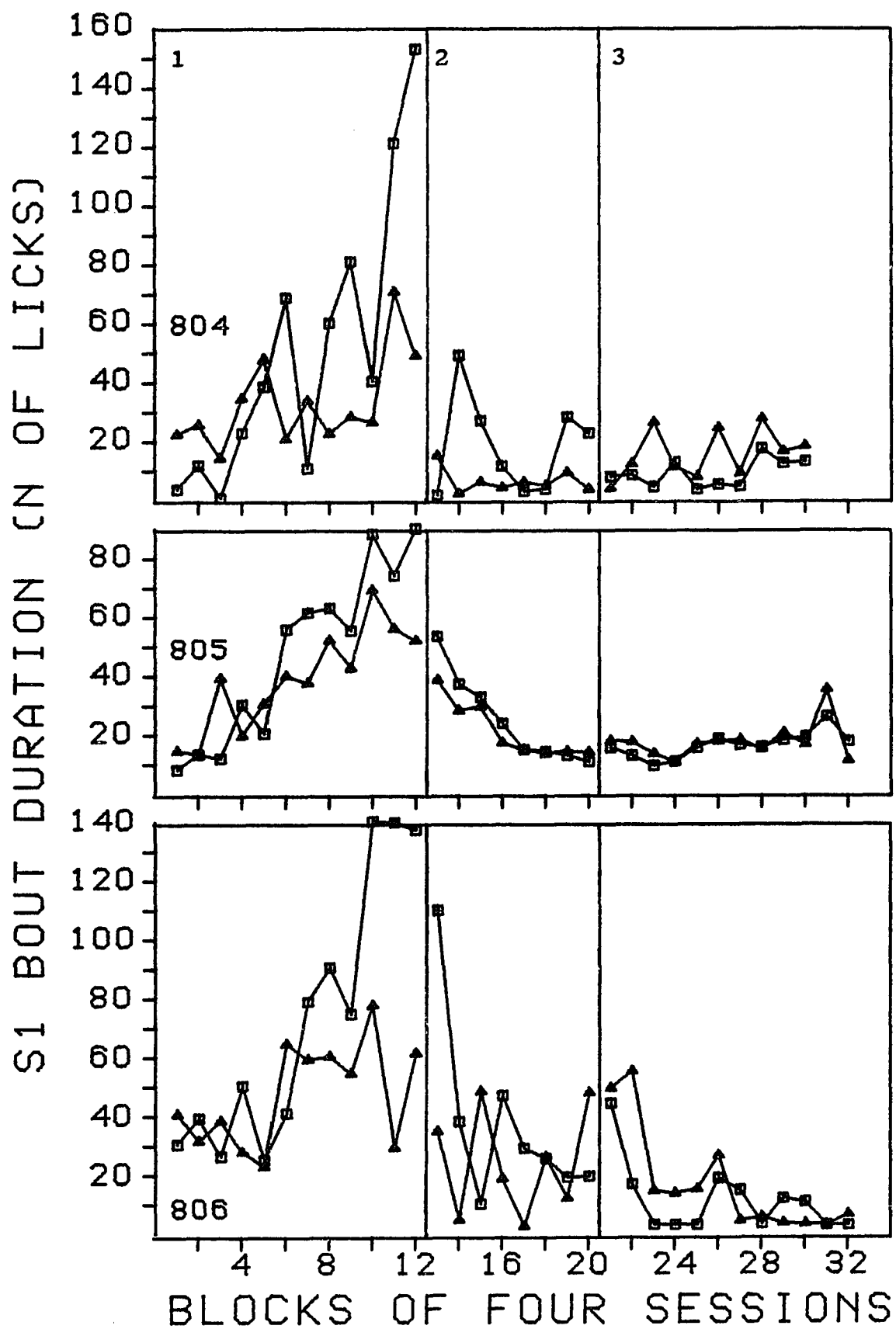
S1 bout durations are presented in Figures 28 and 29 for the 6 experimental subjects exposed to the response-dependent condition. In 5 cases, FS1 bout durations were consistently longer than were SS1 durations at the end of Phase 1. That effect was statistically significant (Table 8, A x E interaction). The difference was eliminated during Phase 2 (Table 8, B x E interaction) and was not recaptured during Phase 3. S1 bout durations

S1 Bout Durations

Figures 28 and 29. Data represent mean number of licks per S1 (post-stimulus, pre-response) lick bout for experimental subjects for which lever-pressing was required (801 - 806). Phases of the experiment are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-fcdd behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with fcdd presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.







were shorter during Phase 2 than during Phase 1 for 5 subjects. Phase 3 durations did not differ from Phase 2 durations.

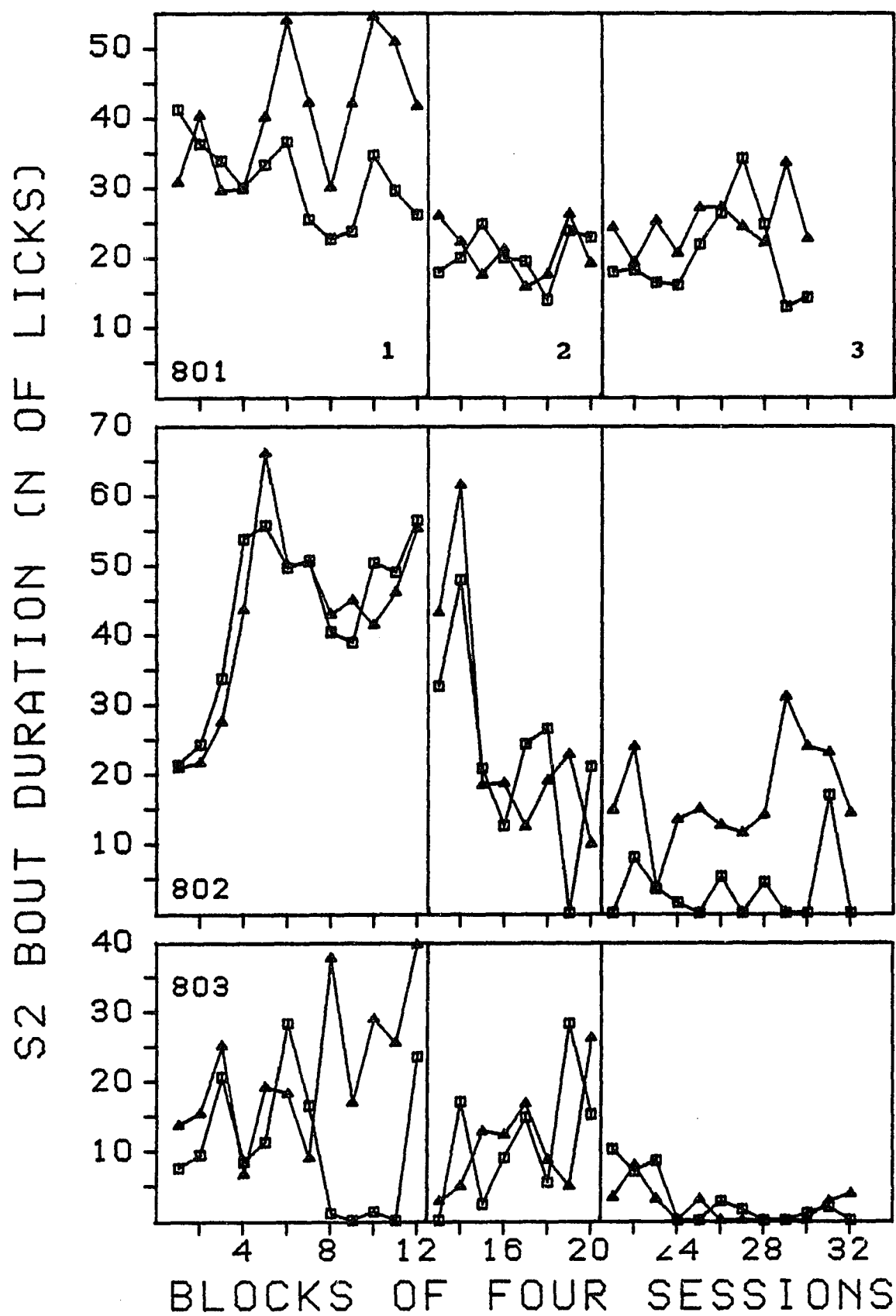
S2 bout durations are presented in Figures 30 and 31. Pre-stimulus bouts were consistently longer than pre-food bouts at the conclusion of Phase 1 for 4 subjects (801, 803, 804, 805). This effect did not appear in the MRA. The difference disappeared during Phase 2, but unlike the difference in S1 bout durations, it generally re-appeared during Phase 3 (not necessarily in the same subjects for which it was present during Phase 1). S2 bout durations during Phase 2 were shorter than those exhibited during Phase 1 for 4 subjects (801, 802, 804, 805). Phase 1 durations were not recaptured during Phase 3.

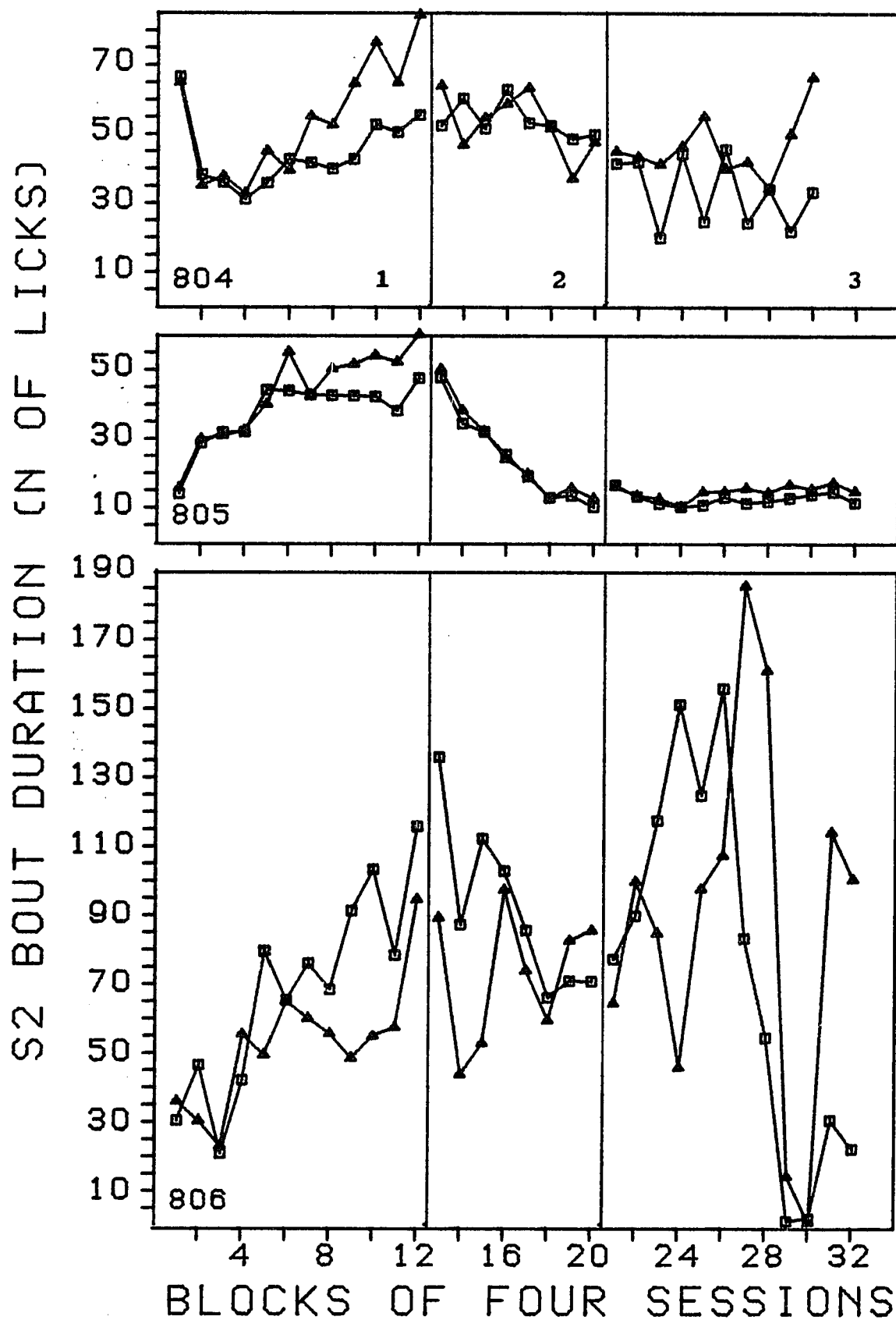
F2 bout durations are presented in Figures 32 and 33. The data were relatively noisy and suggest no pre-food/pre-stimulus difference. In a few cases, F2 bout durations declined during Phase 2 (801, 802, 805), and did not recover during Phase 3.

F1 bout durations are presented in Figures 34 and 35. F1 bouts were clearly longer than F2, S1, or S2 bouts, as was found in the above MRA. Among subjects originally presented with signal pair S2 (Figure 35), pre-food bouts were consistently longer than pre-stimulus bouts at the conclusion of Phase 1. That difference disappeared during Phase 2 and did not appear in the behavior of subjects presented with pair S2 during Phase 3 (Figure 34).

### S2 Bout Durations

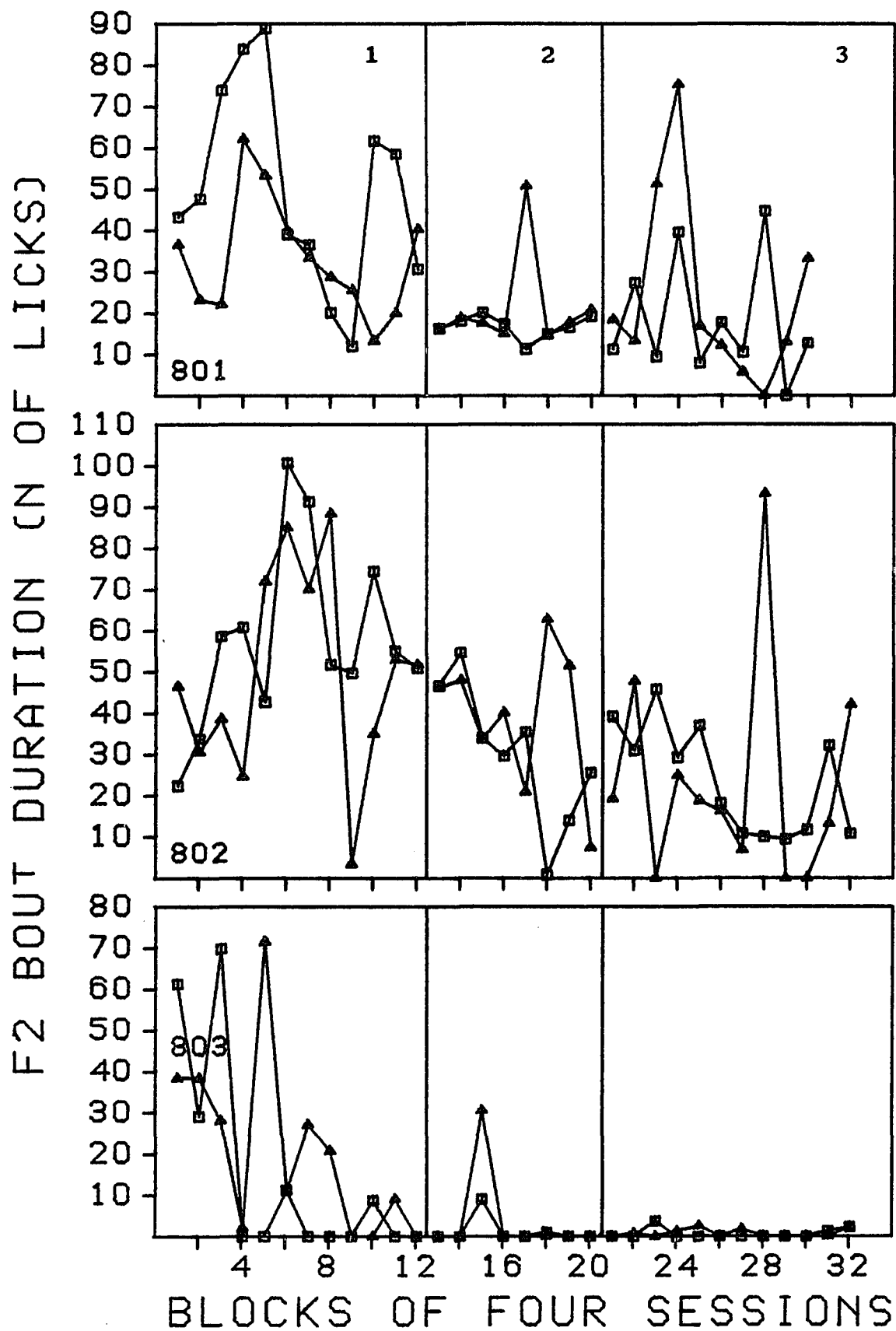
Figures 30 and 31. Data represent mean number of licks per S2 (post-stimulus, post-response) lick bout for experimental subjects for which lever-pressing was required (801 - 806). Phases of the experiment are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.

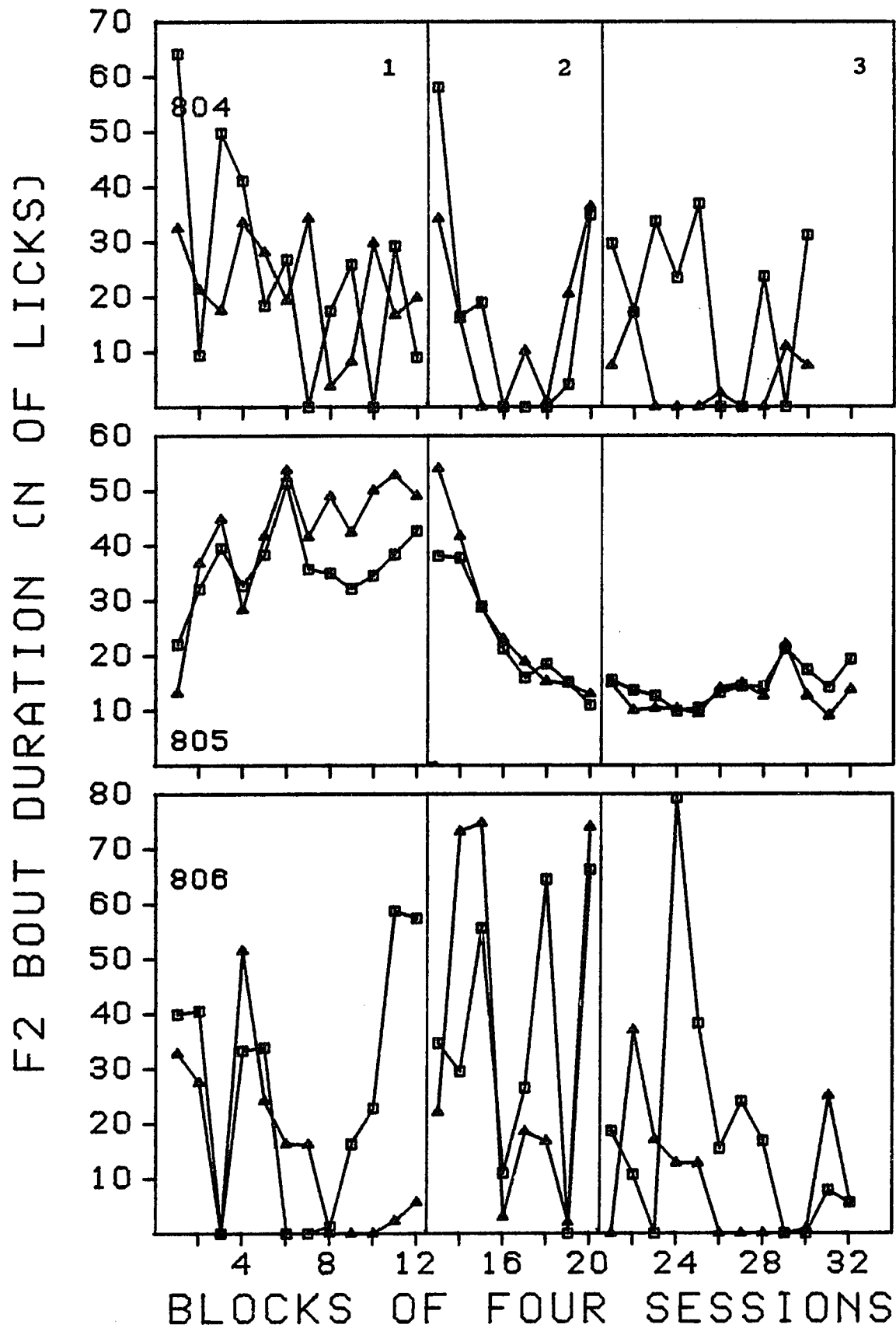




F2 Bout Durations

Figures 32 and 33. Data represent mean number of licks per F2 (post-food, post-response) lick bout for experimental subjects for which lever-pressing was required (801 - 806). Phases of the experiment are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.

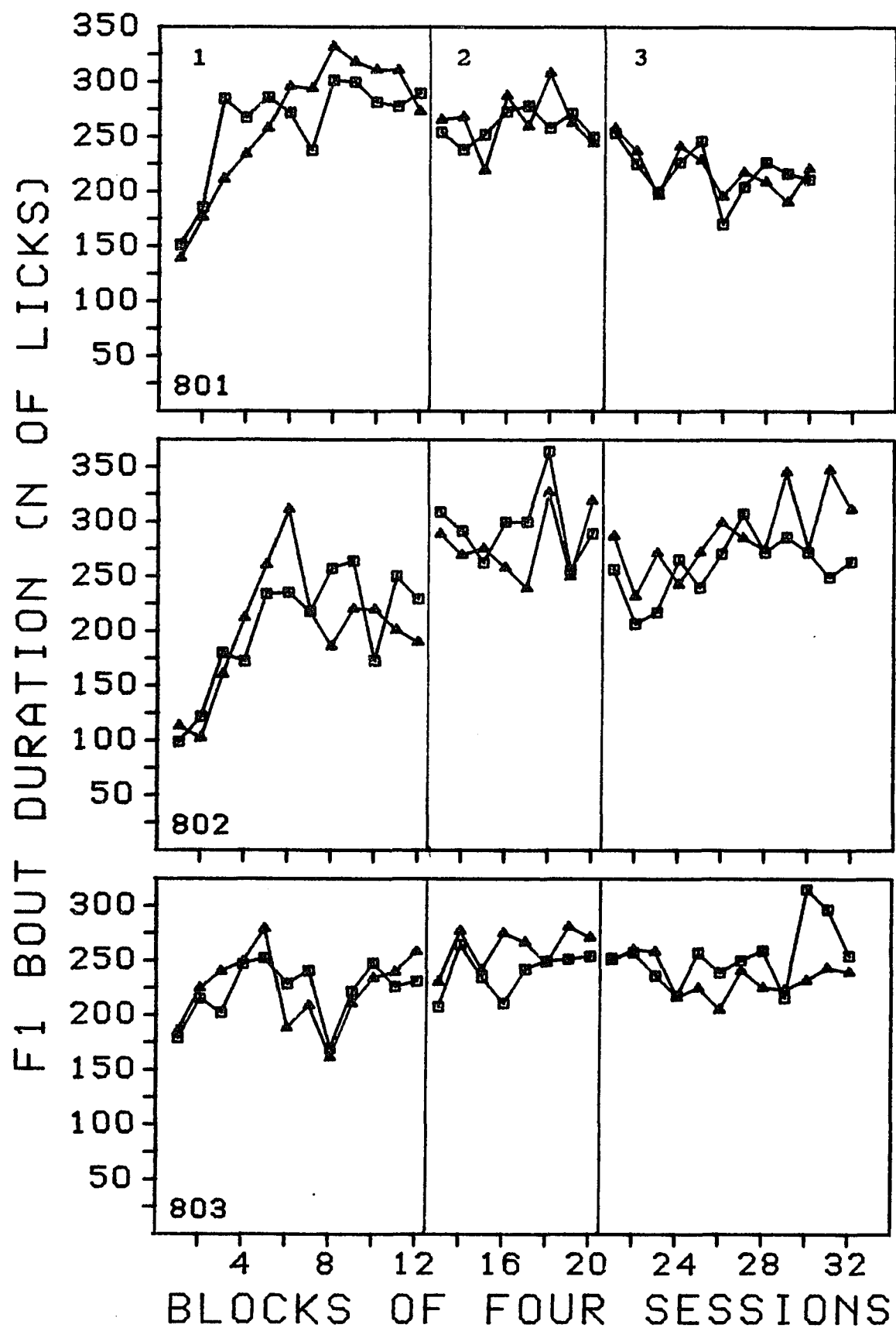


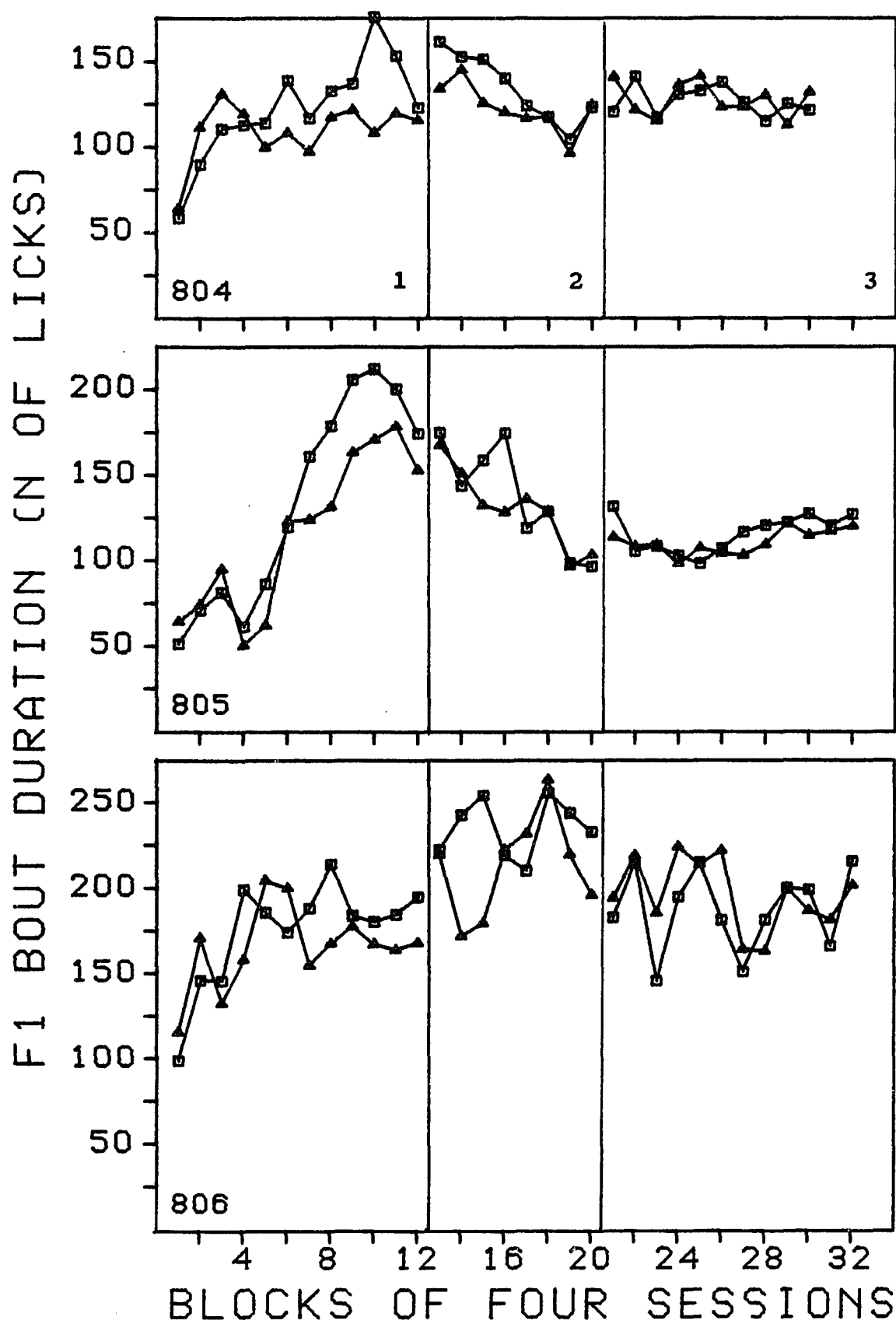




### 3.1 Bout Durations

Figures 34 and 35. Data represent mean number of licks per F1 (post-fccd, pre-response) lick bout for experimental subjects for which lever-pressing was required (801 - 806). Phases of the experiment are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-fccd behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with fccd presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.





The analysis of bout rates was performed in the same manner as were the re-analyses of drinking levels and bout durations. The following contrasts were used in the analysis: average pre-food vs. average pre-stimulus bout rates; average rates when component outcomes were predictable vs. those when outcomes were unpredictable; average rates among subjects originally presented with signal pair S2 vs. those among subjects originally presented with pair S1; average S2 rates vs. average F2 rates; average S1 rates vs. averaged F2 and S2 rates; and average F1 rates vs. averaged F2, S1, and S2 rates. The results are presented in Table 9.

Average bout rates were higher among subjects originally presented with signal pair S2 than among those originally presented with pair S1. Average F1 rates exceeded averaged F2, S1, and S2 rates. The A x F interaction indicates that F1 rates were higher during pre-food than during pre-stimulus components (Figures 38 and 39).

Post-stimulus bout rates are presented in Figures 36 and 37. There were no consistent differences between pre-food and pre-stimulus rates. The transition from Phase 1 to Phase 2 did not have a consistent effect on post-stimulus bout rates, in contrast to the general decrement in post-stimulus bout durations produced by that transition.

Multiple Regression Analysis:

Lick- Bout Initiation Rates

Table 9. Rates of lick bout initiation by Subjects 801 - 806 at the conclusions of Phases 1 and 2 (sessions 45 - 48, 77 - 80) were subjected to a multiple regression analysis.

Note

1. Vectors used in the analysis made the following contrasts: A-- bout rates during pre-fccd components vs. rates during pre-stimulus components; B-- rates when component outcomes were predictable (Phase 1) vs. rates when outcomes were unpredictable (Phase 2); C-- rates among subjects presented with signal pair S2 (Table 2) during Phase 1 vs. those among subjects presented with pair S1 during Phase 1; D-- F2 rates vs. S2 rates; E-- S1 rates vs. pooled S2 and F2 rates; F-- F1 rates vs. pooled F2, S1, and S2 rates. All interactions tested are shown in the table. Interactions not tested were excluded on the basis of very low correlations with bout rates ( $-0.1 < r < 0.1$ ).

Table 9

Multiple Regression Analysis: Bout Rates

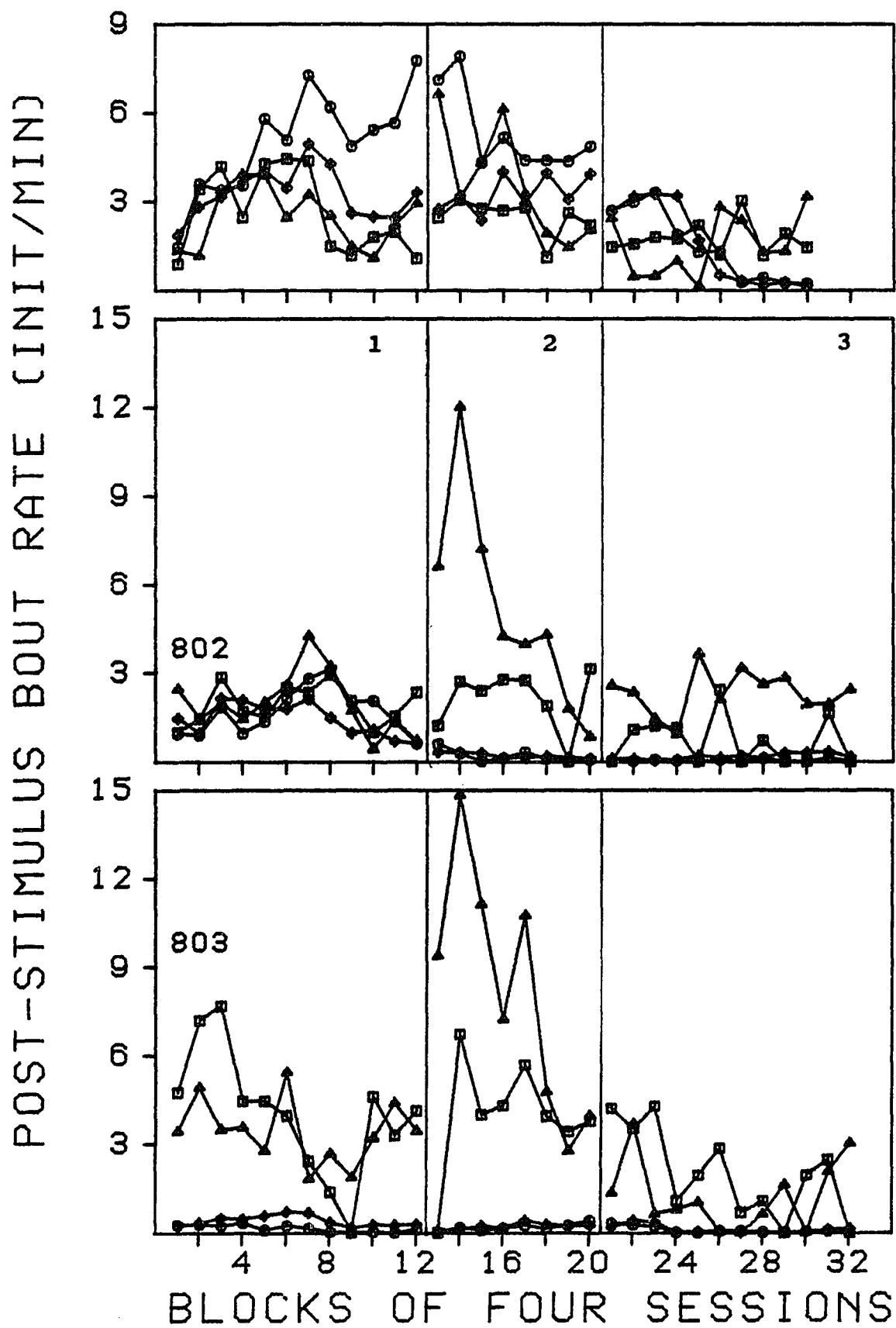
Source (1)	df	SS	MS	F	r-Squared
A. Pre F/S	1	45	45	2.6	0.02
B. Predict	1	24	24	1.4	0.01
C. Sig. Pair	1	179	179	10.6**	0.07
D. S2-F2	1	0	0	0.0	0.0
E. S1-S2, F2	1	18	18	1.1	0.007
F. F1-F2, S1, 2	1	758	758	44.7**	0.28
Interactions					
A x E	1	27	27	1.6	0.01
A x F	1	85	85	5.0*	0.03
B x F	1	55	55	3.2	0.02
C x F	1	40	40	2.3	0.01
Residual	85	1443	17		
Total	95	2674			0.46

\*-- p &lt; 0.05

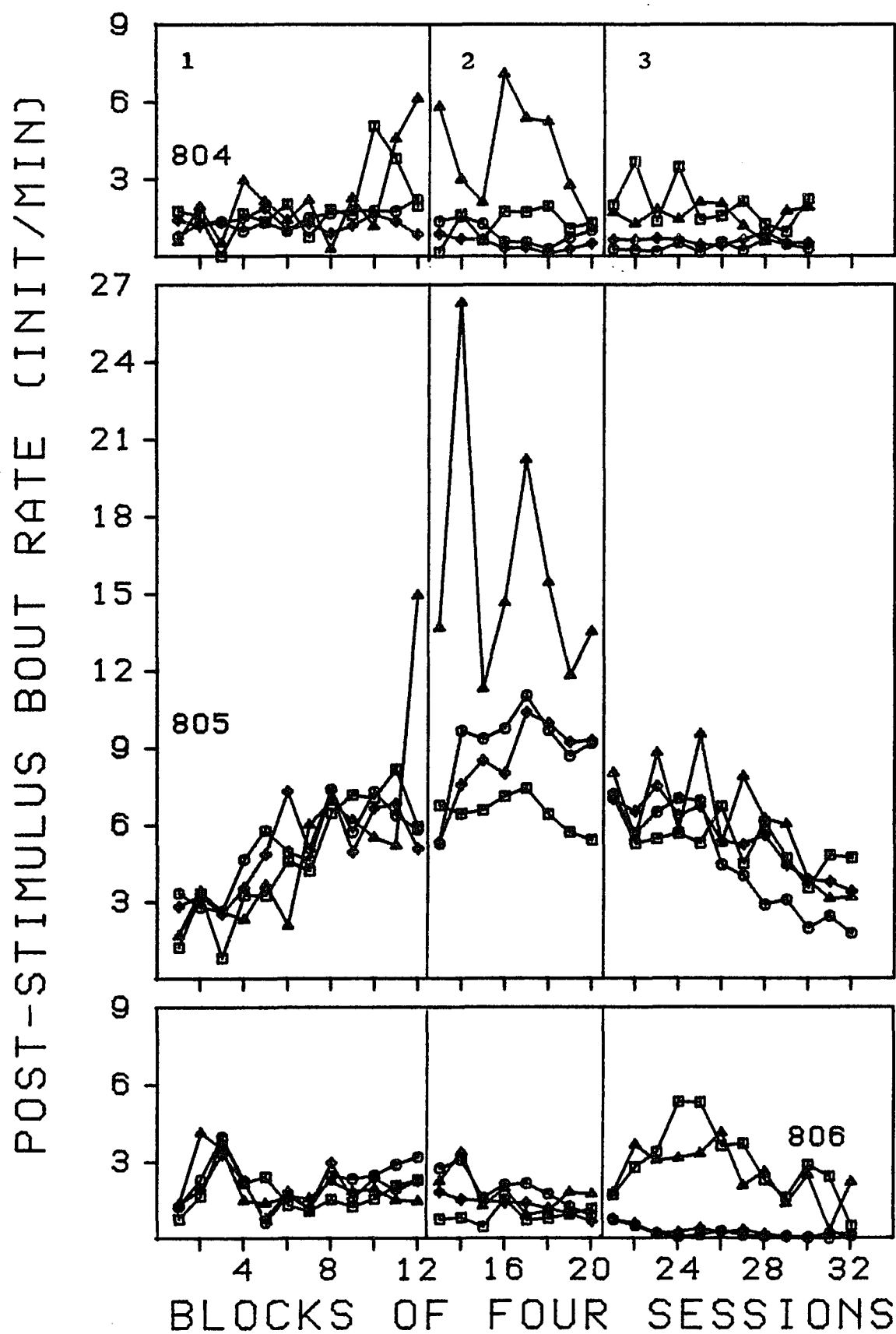
\*\*-- p &lt; 0.01

### Post-Stimulus Bout Rates

Figures 36 and 37. Data represent bout rates, computed as described under General Methods for the 6 experimental animals for which lever-pressing was required (801 - 806). Behavior is broken down according to whether it occurred before (pre-response) or after (post-response) the onset of lever-pressing within components. Individual subjects are identified by 3-digit numbers. Phases of the experiment are identified by 1-digit numbers, and are separated by vertical lines. During Phases 1 and 3, the correspondence between symbols and lick categories (Table 2) is as follows: squares-- FS1; circles-- FS2; triangles-- SS1; and diamonds-- SS2. During Phase 2, squares and circles represent pre- and post-response drinking in the presence of the signal previously correlated with food presentations; triangles and diamonds, pre- and post-response drinking in the presence of the signal previously correlated with stimulus presentations. Individual data points represent behavior averaged over 4 consecutive sessions.







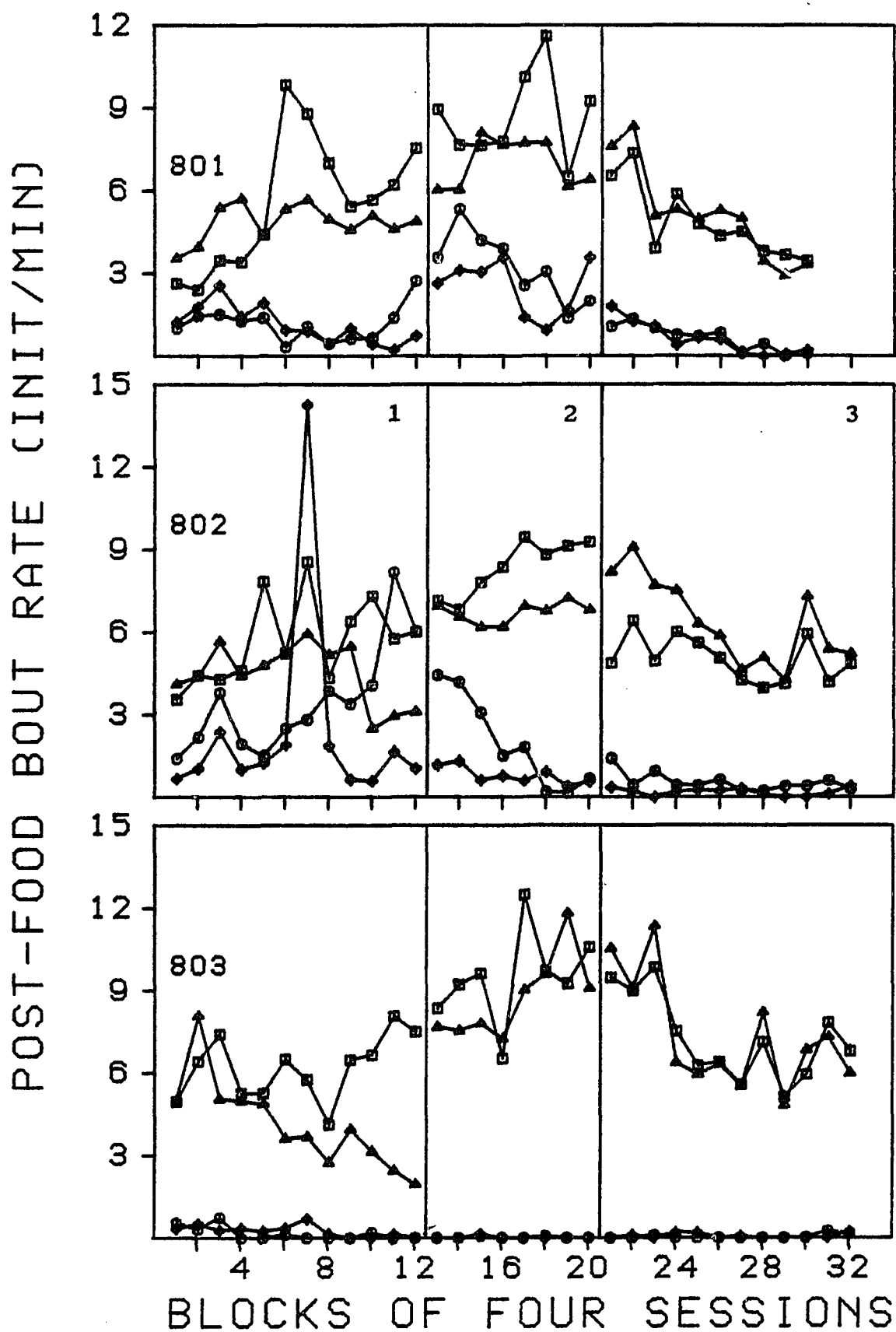
Post-food bout rates are presented in Figures 38 and 39 for the 6 response-dependent experimental subjects. FF2 bout rates were consistently higher than SF2 bout rates in 4 of the 6 cases at the end of Phase 1; there were no cases in which SF2 rates consistently exceeded FF2 rates. The FF2-SF2 difference disappeared during Phase 2 and was not recaptured during Phase 3. FF1 bout rates were consistently higher than SF1 bout rates at the end of Phase 1 for 5 subjects. This difference was probably due in large part to the difference in lever-press latencies (Appendix A). The difference was not reliably affected by the transition from Phase 1 to Phase 2.

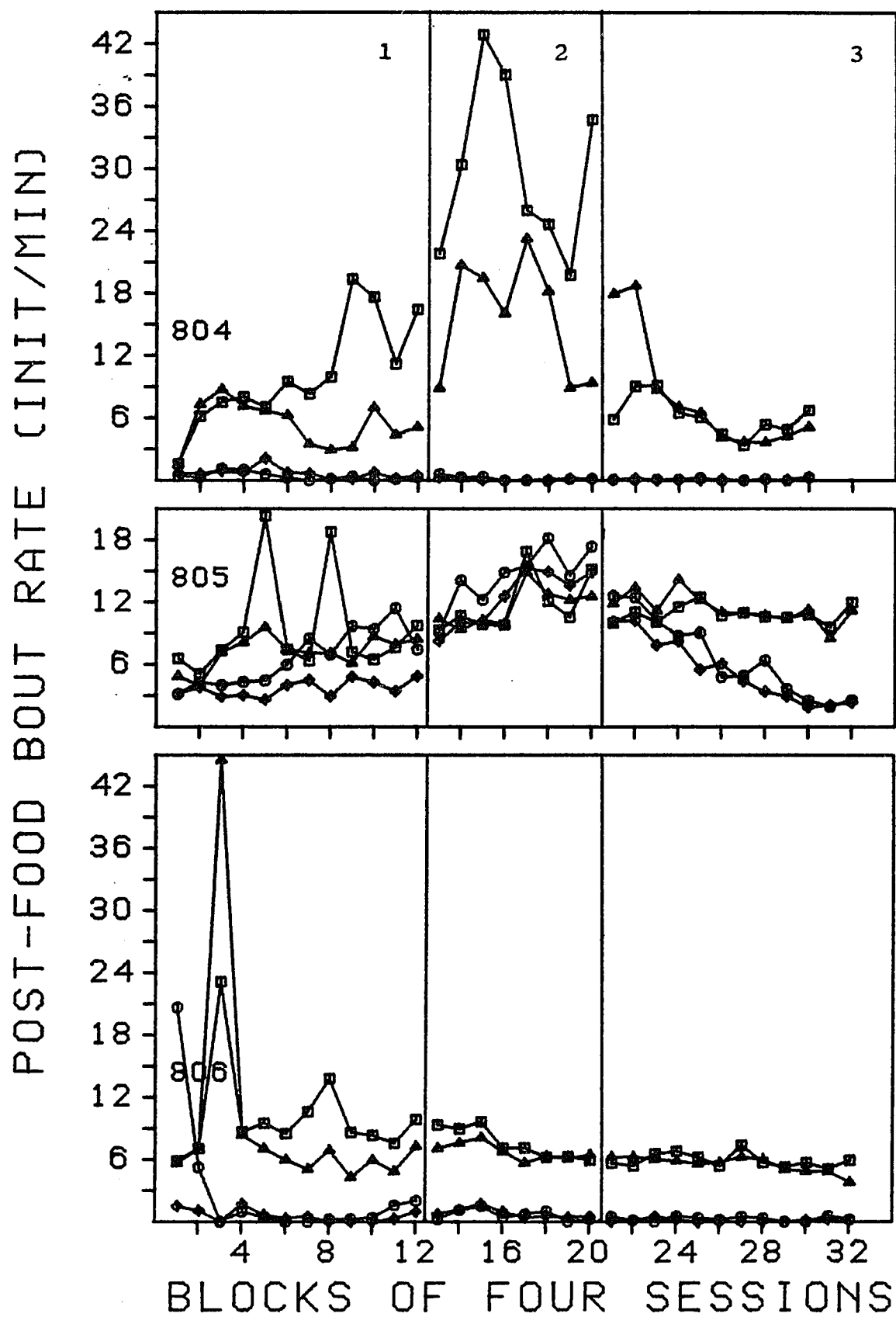
Post-stimulus lick latencies are presented in Figures 40 - 43. It should be noted first that pre-food latencies were consistently shorter than pre-stimulus latencies among 7 of the 9 experimental animals at the end of Phase 1. The difference disappeared during Phase 2 and was generally not recaptured during Phase 3. Second, a comparison of Figure 43 with Figures 40 - 42 will reveal that the average post-stimulus lick latency was typically shorter among the experimental than among the control animals.

IC's for post-stimulus drinking are presented in Figures 44 - 47. At the end of Phase 1, pre-food indices were generally more negative than were pre-stimulus indices for 5 subjects (803, 804, 805, 807, 809). There were no cases in which the reverse was true. Licking therefore tended to occur at a slightly higher rate early than it did

Post-Food Bout Rates

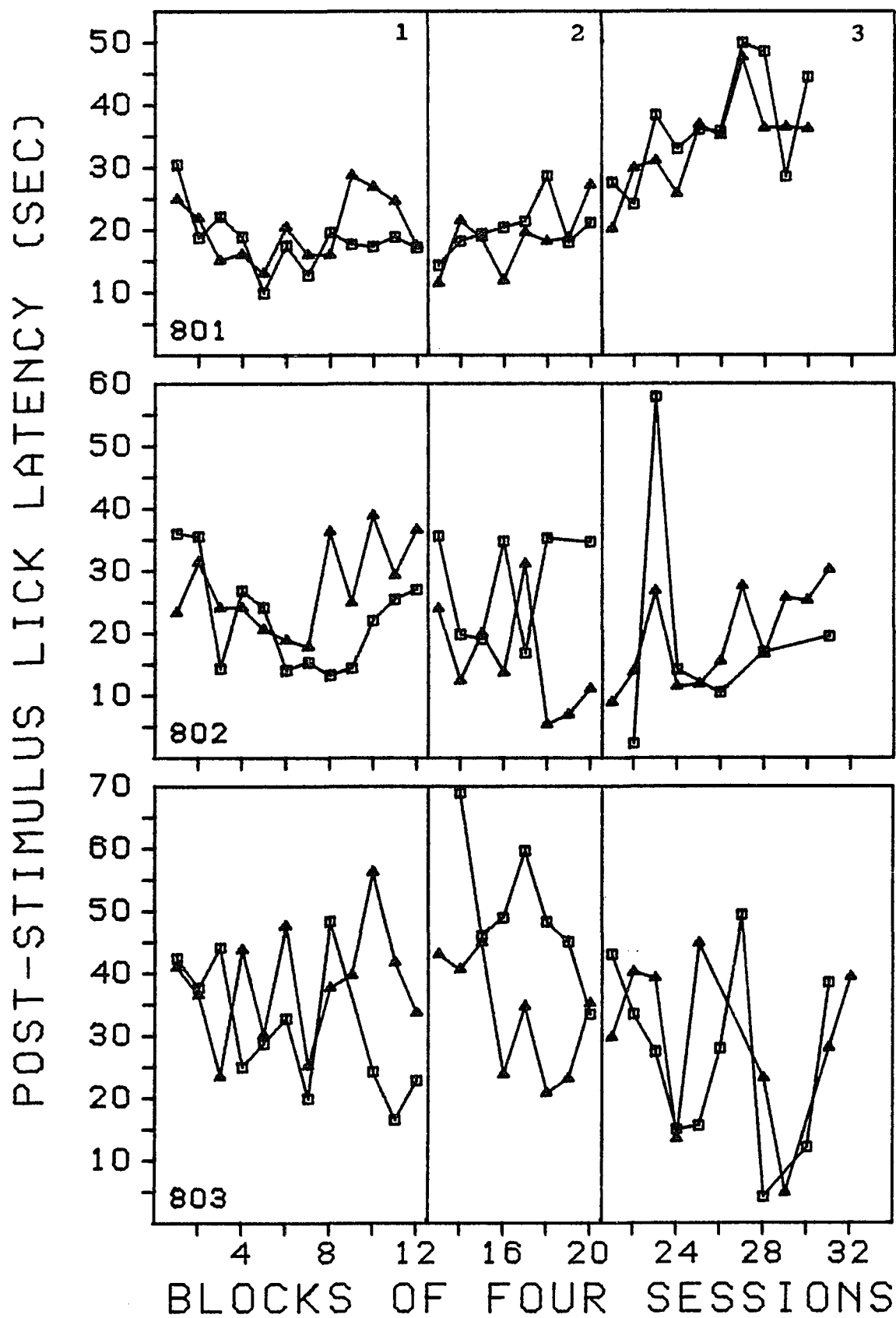
Figures 38 and 39. Data represent bout rates, computed as described under General Methods for the 6 experimental animals for which lever-pressing was required (801 - 806). Behavior is broken down according to whether it occurred before (pre-response) or after (post-response) the onset of lever-pressing within components. Individual subjects are identified by 3-digit numbers. Phases of the experiment are identified by 1-digit numbers, and are separated by vertical lines. During Phases 1 and 3, the correspondence between symbols and lick categories (Table 2) is as follows: squares-- FF1; circles-- FF2; triangles-- SF1; and diamonds-- SF2. During Phase 2, squares and circles represent pre- and post-response drinking in the presence of the signal previously correlated with food presentations; triangles and diamonds, pre- and post-response drinking in the presence of the signal previously correlated with stimulus presentations. Individual data points represent behavior averaged over 4 consecutive sessions.



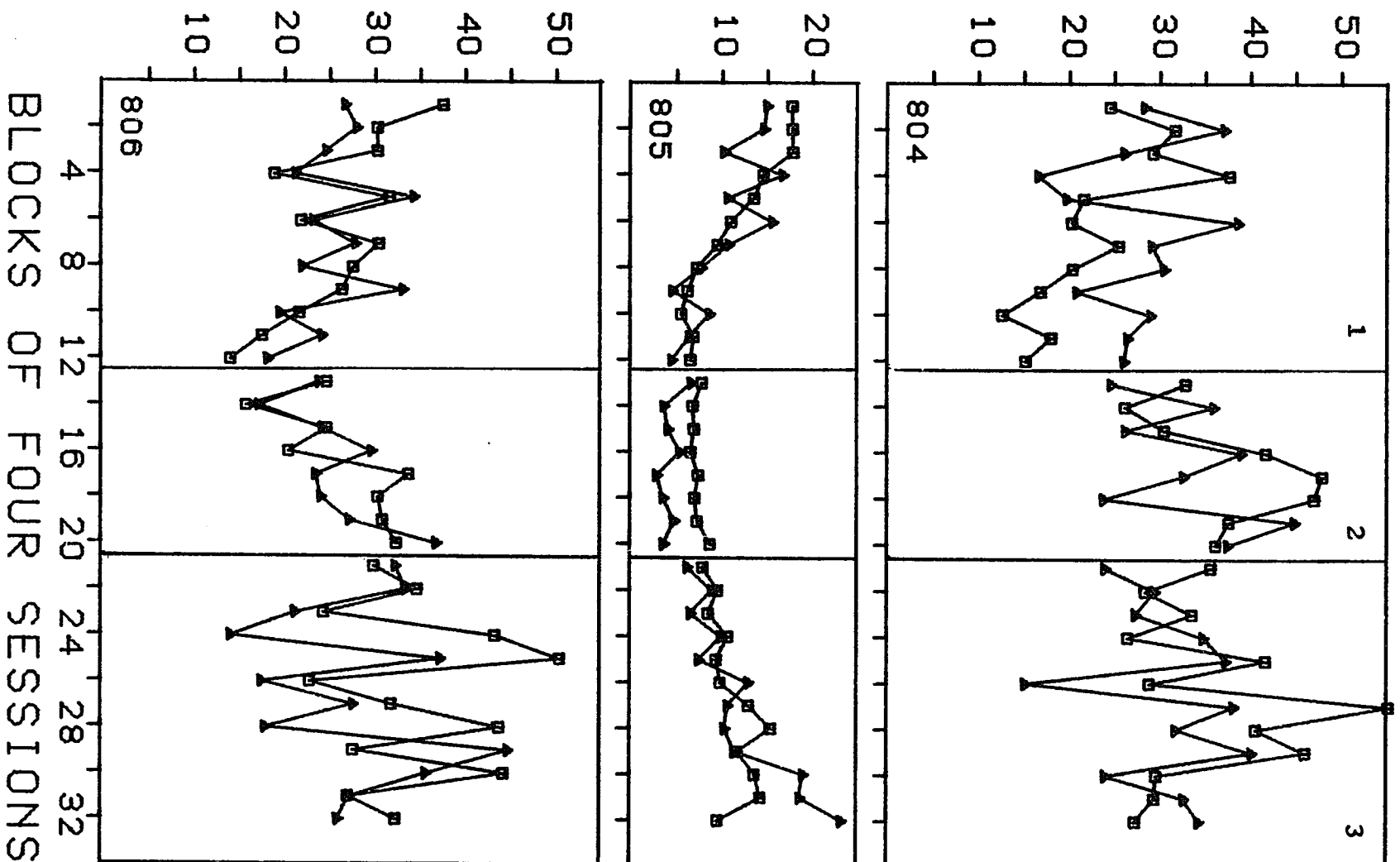


### Post-Stimulus Lick Latencies

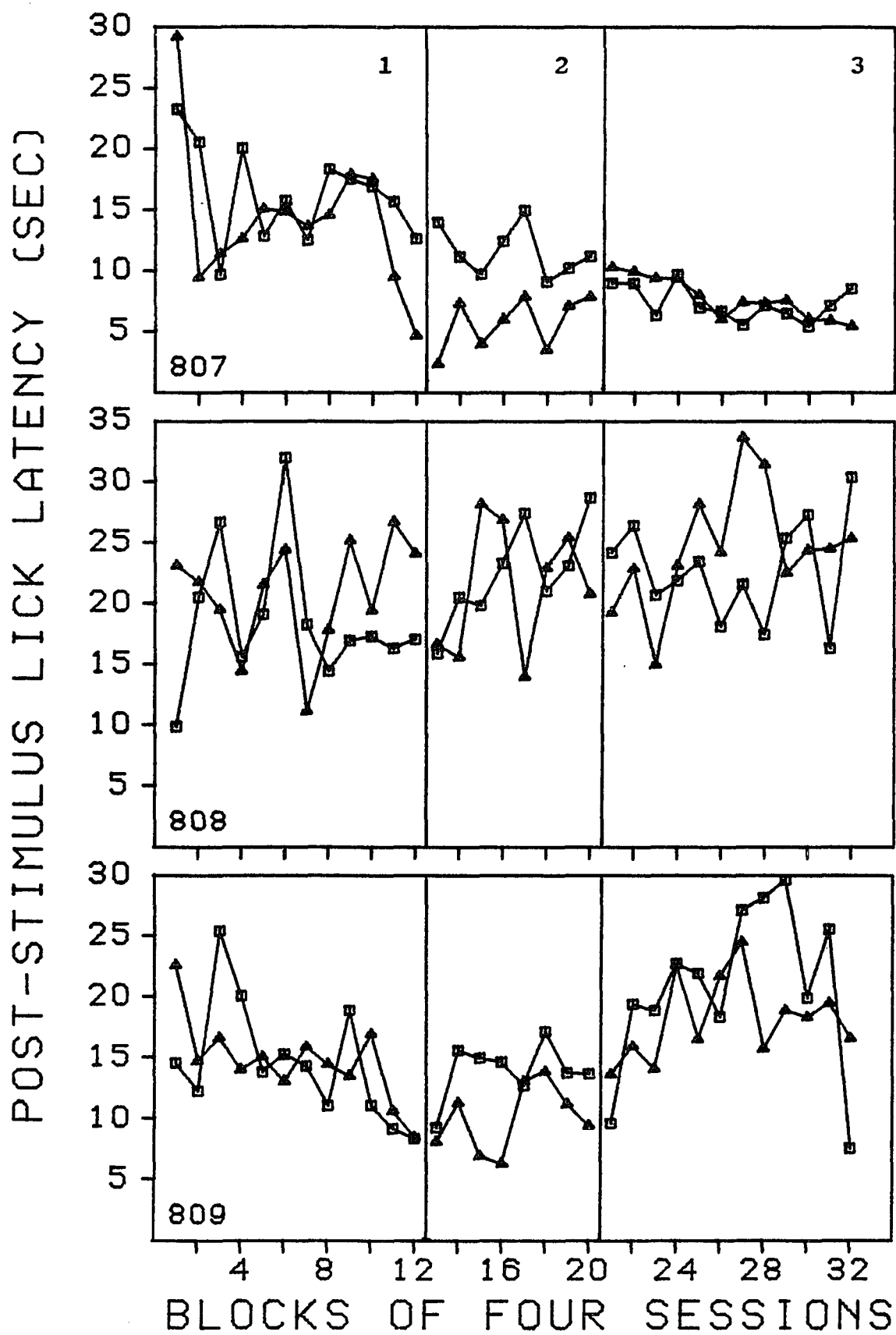
Figures 40 - 43. Data represent the latency to lick (during components in which licking occurred) for all subjects. Latencies were computed as described under General Methods. Phases of the experiment (1 - 3 for experimental subjects, 1 and 2 for control subjects) are identified by 1-digit numbers and separated by vertical lines. Individual subjects are identified by means of 3-digit numbers. For experimental subjects (801 - 809, Figures 40 - 42) during Phases 1 and 3, and for control subjects (811 and 812, Figure 43) during Phase 2, squares represent pre-food (FS) behavior, while triangles represent pre-stimulus (SS) behavior. For experimental subjects during Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. For Subject 810 during Phase 2, squares represent behavior in the presence of the tone; triangles, behavior in the presence of the repetitive click. For control subjects (810 - 812) during Phase 1, squares represent average post-stimulus behavior. Individual data points represent performance averaged over 4 consecutive sessions.

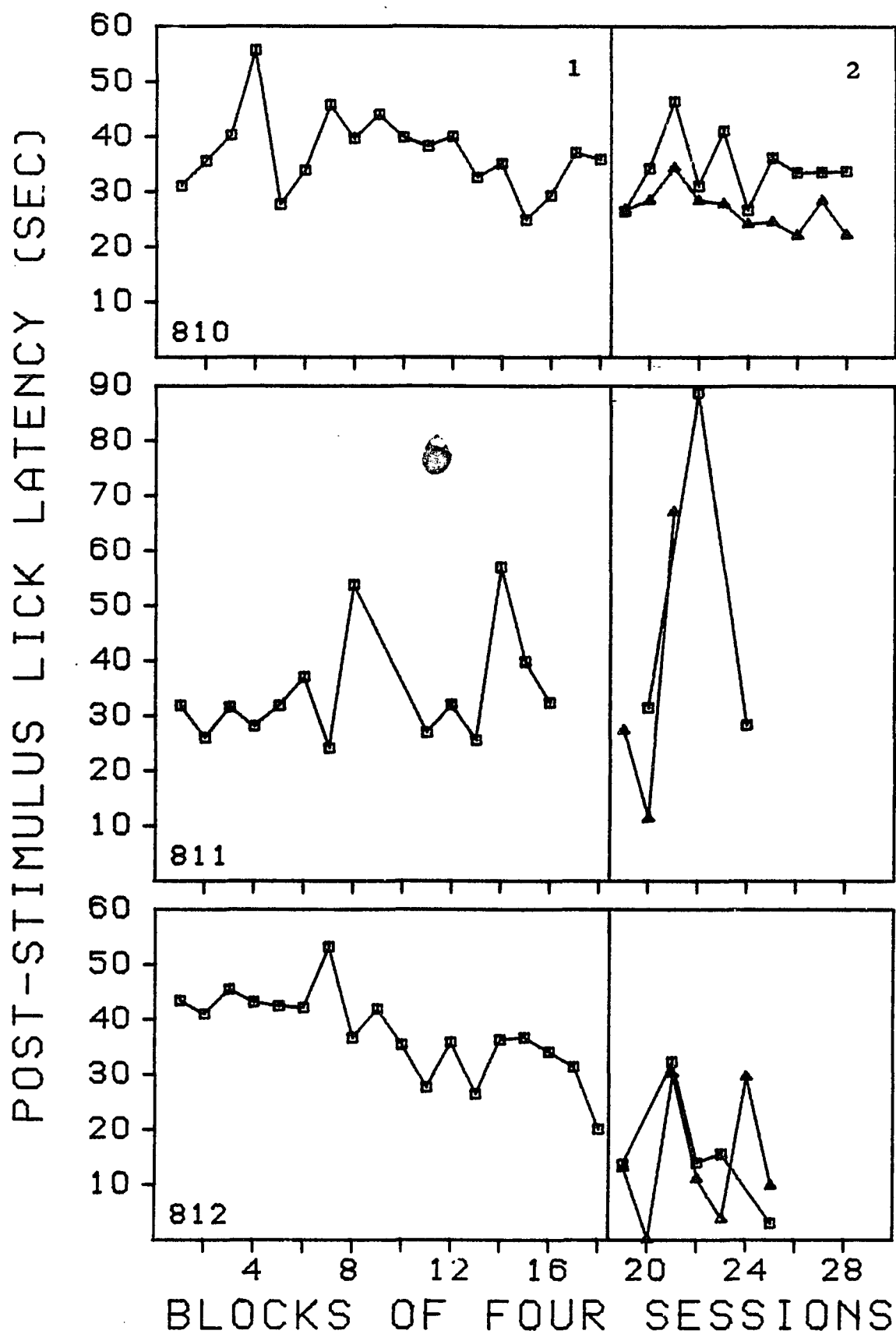


## POST-STIMULUS LICK LATENCY (SEC)



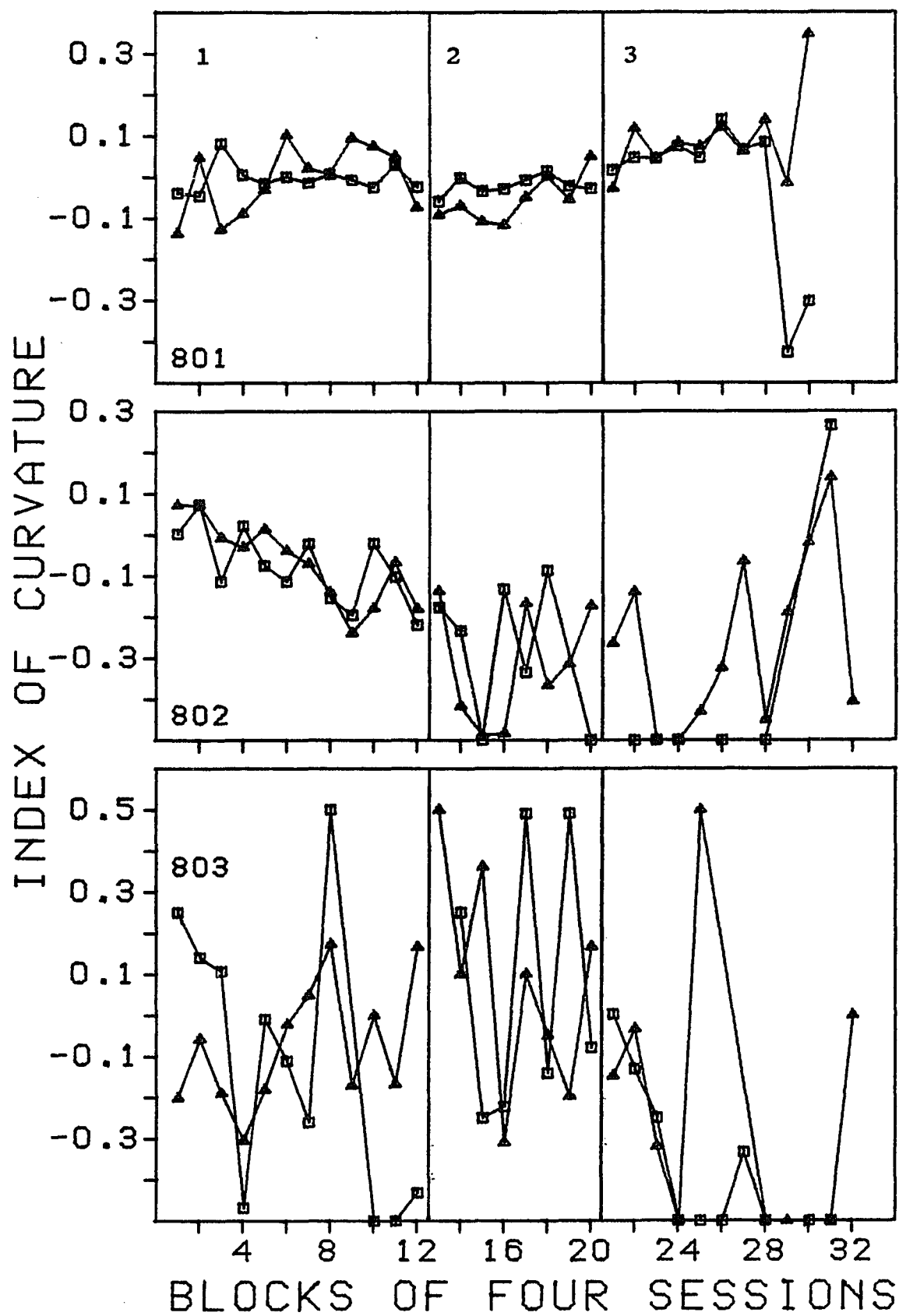


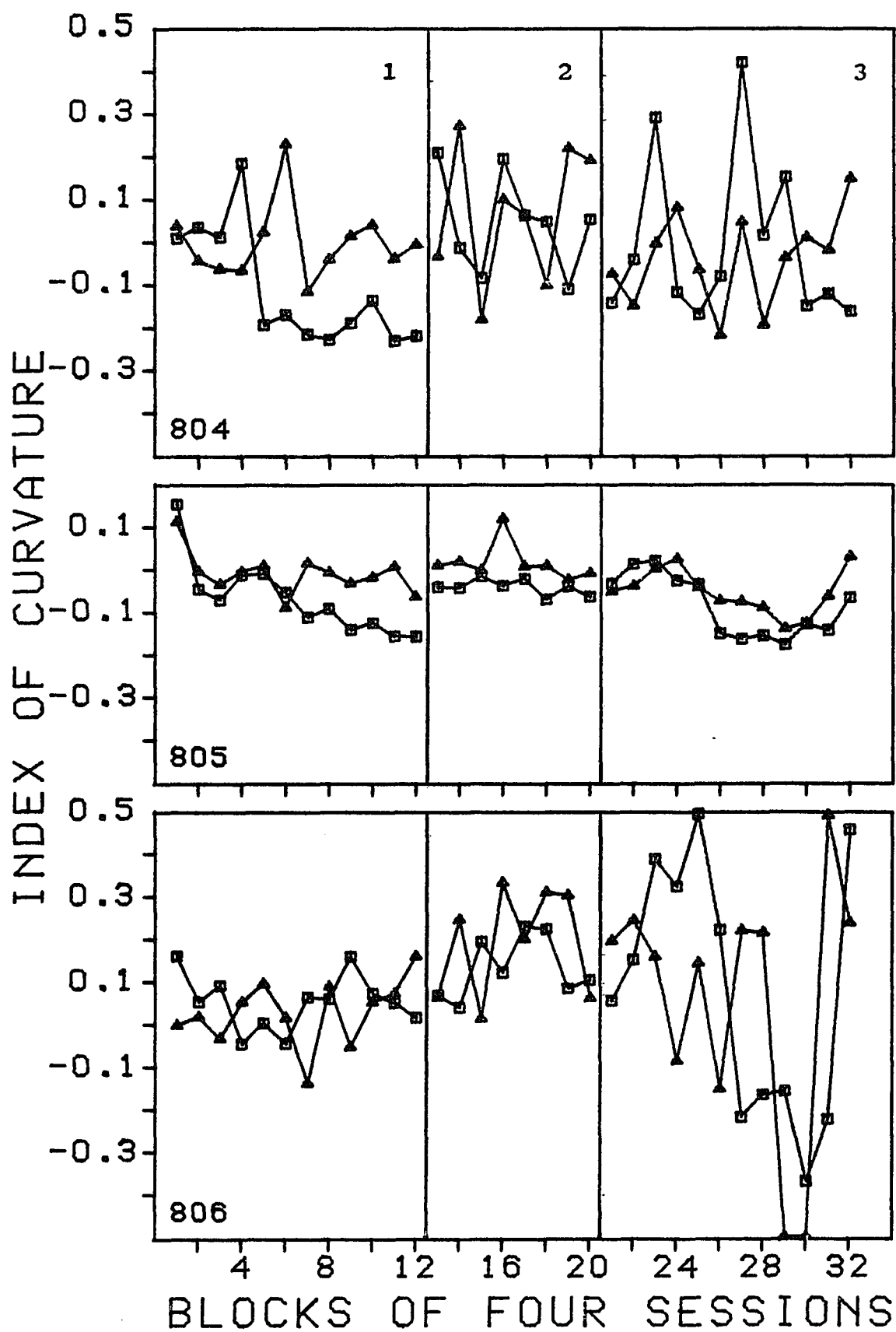


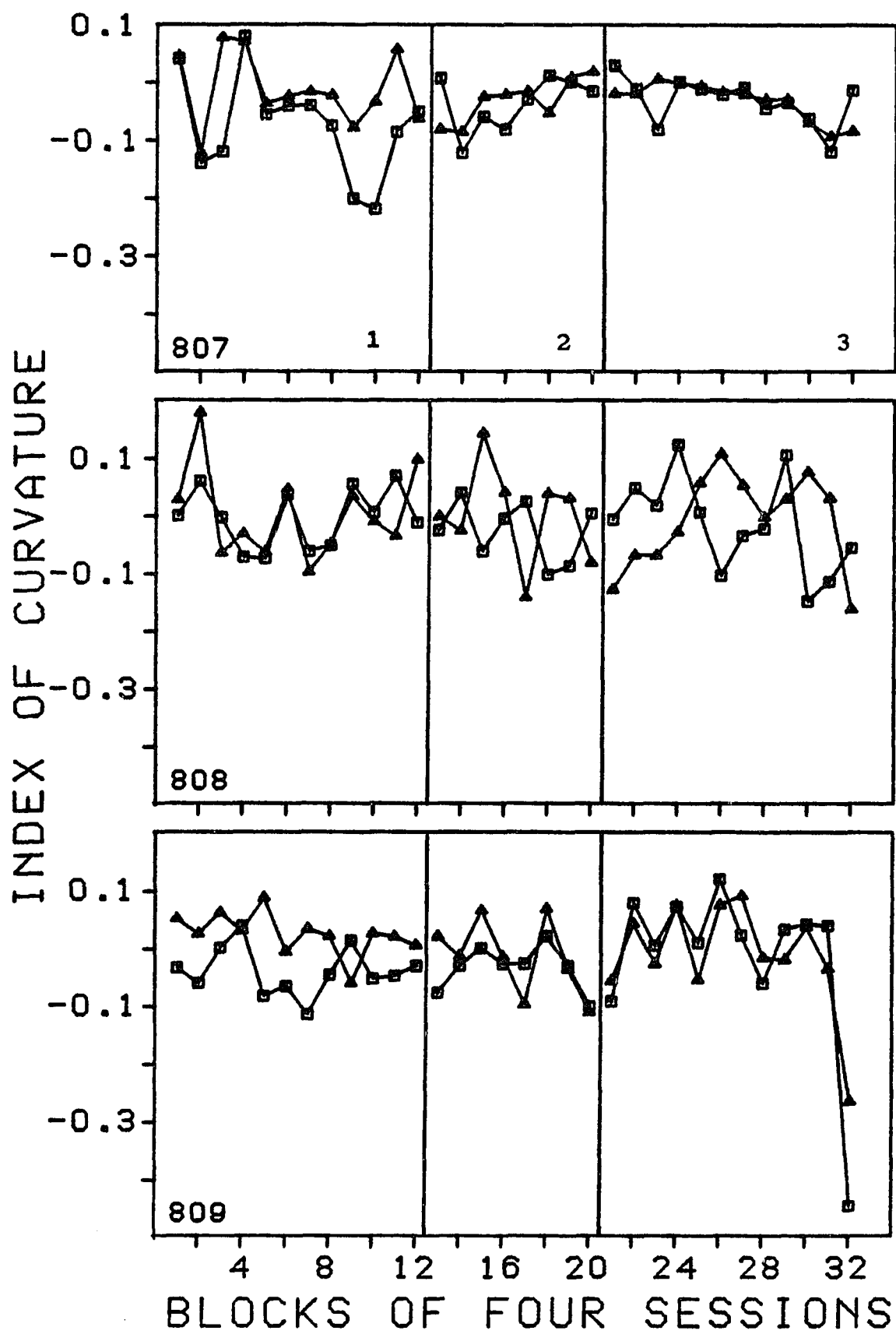


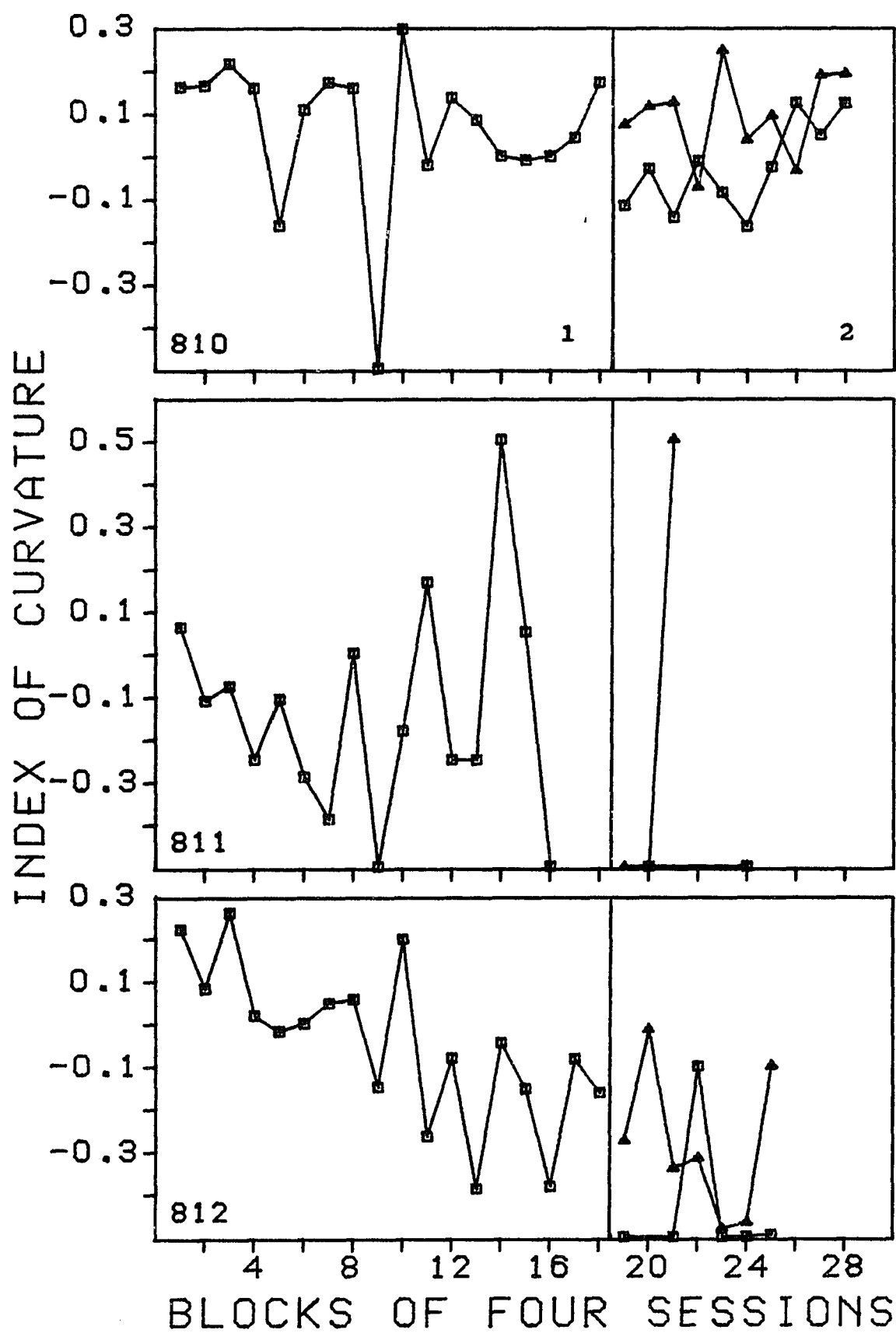
Indices of Curvature:Post-Stimulus Licking

Figures 44 - 47. Data represent indices of curvature, as described under Method, for post-stimulus lick distributions of all subjects. Phases of the experiment (1 - 3 for experimental subjects, 1 and 2 for control subjects) are identified by 1-digit numbers and separated by vertical lines. Individual subjects are identified by means of 3-digit numbers. For experimental subjects (801 - 809, Figures 44 - 46) during Phases 1 and 3, and for control subjects (811 and 812, Figure 47) during Phase 2, squares represent pre-food (FS) behavior, while triangles represent pre-stimulus (SS) behavior. For experimental subjects during Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations; triangles, behavior in the presence of the signal previously correlated with stimulus presentations. For Subject 810 during Phase 2, squares represent behavior in the presence of the tone; triangles, behavior in the presence of the repetitive click. For control subjects (810 - 812) during Phase 1, squares represent average post-stimulus behavior. Individual data points represent performance averaged over 4 consecutive sessions.









late during pre-food components, and to occur at a roughly constant rate during pre-stimulus components. Pre-food lick distributions thus more closely resembled post-food distributions (Preliminary Research; Appendix A) than did pre-stimulus distributions. Pre-stimulus distributions among experimental subjects were similar to the post-stimulus distributions most frequently observed during preliminary research (Figure 6). The effect on lick distributions was not so strong as was the effect on lever-press distributions (Figures 17 and 18). IC's among control subjects during Phase 1 tended to be somewhat more negative than were those of the experimental subjects. However, for that control subject which drank reliably during post-stimulus components (810), the IC was close to 0 as were the pre-stimulus IC's of the experimental subjects. The generally low levels of post-stimulus drinking by control subjects 811 and 812 during Phase 2 make it unwise to attempt to compare pre-food and pre-stimulus distributions of those subjects. Actual lick distributions are presented in Appendix A. During Phase 2, the pre-food patterns evident at the end of Phase 1 were disrupted. By the end of Phase 3, pre-food indices tended to be more negative than pre-stimulus indices in only 3 cases (Subjects 801, 804, 805); there were, however, no cases in which pre-stimulus indices were consistently more negative than pre-food indices.



### Discussion

It is apparent from a consideration of the lever-press data that the conditions of Phase 1 were sufficient to establish a discrimination between the pre-food and pre-stimulus signals. That the discrimination resulted from the correlation between signals and component outcomes, and not from unconditioned stimulus effects of the two signals, is demonstrated both by the decrement in the discrimination during Phase 2, and by the partial acquisition of a reversed discrimination during Phase 3.

For the present purposes, the slow acquisition of a discrimination during Phase 3 is a matter of some concern because it suggests that the set of factors which controlled behavior during Phase 3 was not identical to that which controlled behavior during Phase 1. It would seem, rather, that the factors which were most influential in determining Phase 1 behavior played a diminished role in determining Phase 3 behavior. A number of factors can be invoked to differentiate between the first and third phases of the experiment: the animals were older at the start of Phase 3; they were presumably more acclimated to the reinforcement schedule and to other conditions of the experiment at the start of Phase 3; habituation to the signals may have occurred during Phase 2. The last factor is generally regarded as sufficient to slow conditioning (MacKintosh, 1974), and could explain why acquisition of a discrimination was slower during Phase 3 than during Phase 1. At any rate,

it is clear that comparisons between Phase 1 behavior and Phase 3 behavior must be made cautiously.

Effects of the outcome-correlated signals on drinking were generally weaker and less consistent than the effects on lever-pressing.

Post-food bout rates were greater during pre-food than during pre-stimulus components. That effect is, however, more attributable to time-base differences (Appendix A) than to differences in amount of drinking (Figures 26 and 27). Lever-press latencies were shorter during pre-food than during pre-stimulus components. A given number of F1 lick bouts would therefore yield a higher rate during pre-food than during pre-stimulus components. The greater duration of pre-stimulus components might similarly be expected to give rise to a lower pre-stimulus F2 rate.

S1 bout durations were longer during pre-food than during pre-stimulus components. If bout duration were controlled by the anticipation of food, the same ought to have been true of S2 and F2 bout durations. In fact, S2 bout durations were longer during pre-stimulus than during pre-food components. The effect on S1 bout durations may have been a result of Pavlovian conditioning, as will be described in Experiment 3.

The pre-food/pre-stimulus difference in S2 bout durations could have resulted from the difference in lever-press rates. Animals might have terminated drinking bouts sooner during pre-food components in order to resume

lever-pressing.

There were cases in which the breakdown of drinking into various categories yielded pre-food/pre-stimulus differences in drinking level. Those effects were, however, not consistent. Pre-food levels exceeded pre-stimulus levels in some cases; the reverse was true in others.

The difference between pre-food and pre-stimulus F1 bout durations among subjects presented with signal pair S2 may have been a recording artifact. Levels of short-bout (F2, S1, and S2) drinking were typically higher among those subjects than among those presented with signal pair S1. It may be that subjects in the former group were more likely than were subjects in the latter group to emit occasional brief bursts of licking during the relatively long time which elapsed between the conclusion of long-bout F1 licking and the onset of lever-pressing during pre-stimulus components. The recording instrumentation was incapable of differentiating between long- and short-bout drinking during the pre-response period. Such a behavioral tendency would, however, have shown up as a lower average F1 bout duration during pre-stimulus than during pre-food components as was observed. It might also have contributed to the observation that pre-stimulus F1 drinking levels generally exceeded pre-food F1 drinking levels.

Pre-food/pre-stimulus differences in lick latencies and in lick distributions were observed with some regularity. There is no reason to expect these measures of behavior to

be thus controlled by food anticipation. In fact, if short-bout drinking were a terminal activity, one might well have expected the pre-food index of curvature to be considerably more positive than the pre-stimulus index, as was found for lever-pressing. Experiment 3 will clarify these results.

The data suggest that the short-bout drinking described earlier (F2, S1, S2) might be influenced by the predictability of component outcomes. During Phase 1, 8 of the 9 experimental subjects, but only 1 of the 3 control subjects, acquired reliable post-stimulus drinking. The incidence of post-stimulus drinking among the experimental animals also greatly exceeded that encountered during preliminary research (50% of those subjects drank during post-stimulus components). Removal of the signal-outcome correlation was associated with a clear disruption of post-stimulus drinking in 7 of 9 cases. Comparable disruptions of previously acquired post-stimulus drinking rarely occurred during preliminary research. F2 drinking was similarly disrupted by the transition from Phase 1 to Phase 3. The failure to recover short-bout drinking during Phase 3 is disturbing but inconclusive, inasmuch as Phase 3 was not equivalent to Phase 1 as previously described.

There is little published evidence of an effect of outcome predictability on post-stimulus drinking. Rosenblith (1970) and Allen and Porter (1977) obtained reliable post-stimulus drinking using schedules in which

every third completion of a component resulted in a food presentation. The predictability of the sequence of food and stimulus presentations in those experiments makes them in some ways comparable to the present experiment. Among experiments in which the order of food and stimulus presentations was randomized, only one (Corfield-Sumner, et al., 1977) obtained reliable post-stimulus drinking; 3 did not (Aller and Porter, 1975, 1977; Porter, et al., 1975). Clearly research to explicitly examine the role of outcome predictability in controlling short-bout drinking would be desirable.

The observation that Phase 1 DI's were generally higher during post-food than during post-stimulus components is of interest. It can not be dismissed as an artifact of a difference in component durations, as there was none. It could, however, be related to a difference in the time bases over which lever-press rates were computed. The average time between the onset of lever-pressing and the end of a post-food component was approximately 12 sec; that during post-stimulus components averaged approximately 65 sec. A pre-food/pre-stimulus behavioral difference of a given magnitude would thus have to be maintained over a longer period of time during post-stimulus components than during post-food components. The result of averaging over a longer time base could have been to diminish the difference between pre-food and pre-stimulus rates during post-stimulus components.

Several comparisons can be made between the present data and those obtained in earlier work. Post-food behavior was comparable both to that observed by King and Schaeffer (1973), and to that described under Preliminary Research. Post-stimulus drinking among the experimental subjects during Phase 1 occurred at levels which exceeded those typically observed during preliminary research (Figure 4). Post-stimulus drinking by subjects in the response-independent experimental condition was maintained at levels which compared favorably to those of animals in the response-dependent condition. By contrast, Corfield-Sumner, et al. (1977) reported that very little drinking occurred among animals exposed to a response-independent condition. Again, the enhanced levels of post-stimulus drinking in the present experiment could have been a consequence of the predictability of component outcomes.

It is apparent that evidence for the proposed classification of short-bout (P2, S1, S2) drinking as terminal in nature is weak at best. Pre-food/pre-stimulus differences in drinking were small, while pre-food/pre-stimulus differences in (terminal) lever-pressing were substantial. Pre-food/pre-stimulus differences in lever-pressing were recovered, at least to some extent, during Phase 3; differences in drinking generally were not. If short-bout drinking is, in fact, a terminal activity, its control by the anticipation of food

presentations is clearly much weaker than is the control exercised over lever-pressing by food anticipation.

The data do not fully support the proposed lumping of the short-bout categories of drinking (F2, S1, and S2) into a single behavioral class. The transition from Phase 1 to Phase 2 produced reliable decrements in S2 and S1 bout durations, but not in F2 bout durations. S2 bouts were generally longer than were F2 or S1 bouts. The differences among those categories were, however, slight when contrasted with the difference between them and F1 bout durations. Further work is clearly required before the categorization of drinking into qualitatively different classes can be regarded as valid.

## VII. EXPERIMENT 3:

### DRINKING FOLLOWING PAIRED AND NONPAIRED STIMULI

Several investigations of drinking induced by second-order food schedules have been conducted without reference to the interim-terminal framework proposed by Staddon and Simmelhag (1971). In particular, Rosenblith (1970), who employed a PR 3 (FI 60:Sp) schedule, regarded post-stimulus drinking as an outcome of Pavlovian conditioning.

The Pavlovian paradigm (Pavlov, 1927) relies upon the reliable elicitation of a particular response pattern (UR, unconditioned response) by presentations of a particular stimulus (US, unconditioned stimulus). For example, salivation (UR) can be elicited in dogs by the placing of food powder (US) into the mouth. Pavlovian conditioning occurs when presentations of some new stimulus (CS, conditioned stimulus) are added to the situation in such a way as to reliably predict occurrences of the US. Under these conditions, the CS may gradually come to elicit a response pattern (CR, conditioned response) similar to that controlled by the US. Thus, if the placing of food powder into a dog's mouth (US) is reliably preceded by the sound of a metronome (CS), originally irrelevant to the control of salivation, then after a number of metronome-food (CS-US)



pairings, the metronome may itself become capable of eliciting salivation (CR).

An analogy can be made between various elements of the Pavlovian conditioning situation and elements of the situation in which drinking is induced by a reinforcement schedule. Once drinking has been acquired, it is common to observe long bouts of drinking following each food presentation. Thus food presentations are analogous to US's which control (F) drinking as a UR.

Rosenblith (1970) suggested that the click-light combination which accompanied food presentations in her experiment might be regarded as a Pavlovian CS. If the analogy with Pavlovian conditioning were valid, one then ought to expect that drinking would come under the control of the click-light combination. Exactly that was observed by Rosenblith.

That the acquisition of post-stimulus drinking lagged behind that of post-food drinking, and reached a lower asymptotic level, supports Rosenblith's contention. If post-stimulus drinking occurred as a CR, it could not develop until after post-food drinking had been acquired and occurred reliably enough to function as a UR. Further, as reported by Rosenblith (1970) and confirmed by Allen and Porter (1977), an increase in the size of the food reinforcer was accompanied by an elevation in the levels of post-stimulus drinking. A similar correlation between US and CR magnitudes is often observed during Pavlovian

conditioning procedures (MacKintosh, 1974) .

A logical extension of Rosenblith's work and her interpretation of post-stimulus drinking would be to compare drinking after presentations of food-paired stimuli with drinking after presentations of stimuli which are never paired with food. To the extent that Pavlovian conditioning, as described by Rosenblith (1970), contributes to the acquisition of post-stimulus drinking, post-stimulus drinking should be maintained at a higher level following food-paired (Sp) than following food-nonpaired (Sn) stimuli during exposure to second-order schedules.

Allen and Porter (1977) used a between-subjects design to compare post-Sp and post-Sn drinking. No difference was found, but neither was post-stimulus drinking reliably obtained, except from a minority of subjects. Clark (unpublished observations, 1979) transferred 2 subjects to a VR 2 (FI 80:SP) second-order schedule after 175 sessions of training with a VR 2 (FI 80:SN) schedule. Neither subject drank reliably during post-stimulus components in either condition. Lever-press latencies were, however, markedly longer in the Sp than in the Sn condition, demonstrating that the stimulus change was relevant in some way to the animals' behavior.

Clark (unpublished observations, 1980) transferred 3 rats from a Sn second-order schedule in which licking was required (Experiment 1b, Subjects 703, 704, 707) to a Sp second-order schedule in which licking was not required.

The amount of post-stimulus drinking declined steadily during the 27 sessions of exposure to the latter schedule, demonstrating an inability of the paired stimulus to maintain drinking previously maintained, at least in part, as an operant response. As with earlier work (Clark, 1979), lever-press latencies were uniformly longer during exposure to the Sp schedule than during exposure to the Sn schedule (mean of 44 sec vs. mean of 9 sec).

In summary, there have been no successful demonstrations of the post-Sp/post-Sn differences in drinking that would be expected on the basis of a Pavlovian model. Rosenblith (1970) obtained reliable post-Sp drinking, but did not make a comparison with post-Sn drinking. Other experiments, which have attempted to make the necessary comparison, have been handicapped by a low incidence of post-stimulus drinking among experimental subjects. Clark (1980), however, found a difference between post-Sp and post-Sn levels of drinking, but that observation was confounded with a change in other conditions of the experiment (lick contingency).

Experiment 3 was conducted in an attempt to improve upon previous comparisons of drinking following presentations of food-paired and food-nonpaired stimuli during exposure to second-order schedules. The results are reported here because they clarify some of the results of Experiment 2-- pre-food/pre-stimulus differences in lick and lever-press distributions, and in lick latencies. The

results offer an alternative explanation, also, for the observation that pre-food S1 bouts were longer than pre-stimulus S1 bouts.

### Experiment 3a

Previous comparisons of drinking after food-paired (Sp) and food-nonpaired (Sn) stimuli have suffered either from a general failure to obtain post-stimulus drinking (Allen and Porter, 1977; Clark, 1979, unpublished observations), or from the failure of paired stimuli to maintain drinking previously maintained by a contingency (Clark, 1980, unpublished observations). In the present experiment, a contingency was in effect throughout, thereby insuring that at least a small amount of drinking would occur in all components. The confounding of stimulus types with changes in the requirements of the schedule from which Clark's (1980, unpublished) work suffered was also thereby avoided.

### Method

Subjects. Two albino rats, Subjects 704 and 707, had previously participated in Experiment 1b and in preliminary work described above (Clark, 1980, unpublished observations). The present experiment began during session 141 of experience with second-order schedules for Subject 704, and during session 153 for Subject 707. As in earlier work, both were maintained at 80% of their free-feeding weights.

Procedure. Both subjects were exposed to the following sequence of treatments following the conclusion of Experiment 1b: VR 2 (FI 70:Sn), no contingency-- 23 sessions; VR 2 (FI 70:Sp), no contingency-- 30 sessions; VR 2 (FI 70:Sn), no contingency-- 10 sessions.

After the training described above, a contingency was put into effect such that a bout of licking (see General Methods) was required during each component. The temporal location of the bout was unrestricted, in contrast to the contingency of Experiment 1b. Both animals received 10 sessions of training with the contingency [VR 2 (FI 70:Sn)]. Thereafter, single sessions in which food-paired stimuli were presented [Sp sessions-- VR 2 (FI 70:Sp)] alternated with blocks of five sessions in which nonpaired stimuli were presented [Sn sessions-- VR 2 (FI 70:Sn)]. The contingency was in effect during all sessions.

Two types of paired stimuli were used. It will be recalled that food presentations were accompanied by illumination of a light and were followed by a 2-sec auditory stimulus, a repetitive click in this case. During Sp sessions 1, 4, and 5 (Sp-L), only the light was presented (2-sec duration) when food was omitted. During Sp sessions 2, 3, and 6 (Sp-LC), the stimulus consisted of both the light and the click: the light alone was on during the first 2 sec of stimulus presentations; both light and click were presented during the final 2 sec of the 4-sec stimulus presentations (simultaneous offset of both light and click).

The stimulus presented during Sn sessions was a 2-sec tone.

### Results

The principal results of the experiment are shown in Table 10.

First, lever-press latencies were longer during Sp sessions than during Sn sessions for both rats, and Sp-L and Sp-LC latencies were similar. Second, indices of curvature (IC's) were more positive during post-Sp than during post-Sn components. The difference in distributions suggests a greater similarity of post-Sp than of post-Sn lever-pressing to post-food behavior. Third, the level of post-stimulus drinking (licks per component) did not differ between Sp and Sn sessions. Fourth, the IC which represented the distribution of post-stimulus licking was more positive during post-Sp than during post-Sn sessions for Subject 704. Finally, lick latencies were somewhat longer during Sp sessions than during Sn sessions for both subjects, and Sp-LC latencies were longer than Sp-L latencies.

### Discussion

Post-stimulus drinking levels (Table 10) may be compared to those observed during Experiment 1b ( $49 \pm 10$ ,  $96 \pm 19$  for Subjects 704 and 707 respectively, averaged over the final 5 sessions of training with the contingency in Experiment 1b). The difference in drinking levels may be a

Table 10

Experiment 3a: Results

	704				!	707			
	!Sp-L	!Sp-LC!	Sp!	Sn	!	!Sp-L	!Sp-LC!	Sp!	Sn
	!	!	!	!	!	!	!	!	!
!Lever-	!	!	!	!	!	!	!	!	!
!Pressing:	!	!	!	!	!	!	!	!	!
! Latency	!39+6	!35+17!	37!	19+4	!19+7	!21+10!	20	!10+2!	
! IC	!.23	!.22	!.22!	.01	!.32	!.32	!.32	!.11!	
!Licking:	!	!	!	!	!	!	!	!	!
! Latency	!49+15!	59+9	!	54!50+12	!55+4	!64+10!	60	!49+5!	
! Level	!17+5	!20+5	!	19!20+6	!13+5	!15+2	!	14	!12+4!
! IC	!.03	!.37	!.20!	-.06	!-.18	!-.22	!-.20!	.11!	

Differences between post-Sp and post-Sn behavior in Experiment 3a are summarized. Table values for latencies and drinking levels represent means and standard deviations. Only means are shown for indices of curvature. The Sp columns represent mean data for all Sp sessions, Sp-L columns for Sp-L sessions only, Sp-LC columns for Sp-LC sessions only. Sn values represent mean performance for those Sn sessions which directly preceded a Sp session.

consequence of the difference in the contingencies on licking. It will be recalled that in Experiment 1b, the contingency required that a bout of licking occur at least 70 sec after the start of a component. In the present experiment, there was no restriction as to the temporal locus of the required lick bout. Thus a lick bout early in a component was as effective as a late lick bout in setting up the consequence for a lever-press in the present experiment. One might expect that the time which elapsed between a lever-press's producing a scheduled consequence, and the lick bout which set up that consequence, would, on average have been shorter in Experiment 1b than in the present experiment. Put another way, the contiguity between licking and its consequence may have been greater in Experiment 1b than in the present experiment. That could be sufficient to explain the difference in drinking levels (MacKintosh, 1974).

The data do not convincingly demonstrate a role for Pavlovian conditioning in the control of post-stimulus drinking. Drinking levels did not differ between Sp and Sn sessions. The effect of the Sp stimulus on the lick distribution of Subject 704 paralleled that on lever-pressing. If drinking were occurring as a CR, then its distribution ought to be opposite that of lever-pressing, as is seen during post-food components.



A serious problem is presented by the long lick latencies, which were often longer during Sp sessions than during Sn sessions. If the Sp stimulus were acting as a Pavlovian CS, then one would expect the latency to be shorter during Sp sessions than during Sn sessions.

It may be that the post-stimulus drinking observed in the present experiment occurred, like lever-pressing, as an instrumental response-- both were required to satisfy the requirements of the schedule. Further, the lick and lever-press latencies were affected in the same way by the type of stimulus presented-- both were longer during Sp sessions than during Sn sessions.

A requirement for a stimulus to act as a Pavlovian CS is that there be a high correlation between presentations of that stimulus and presentations of the US. The manner in which the present experiment was conducted was such as to decrease the correlation between Sp stimuli and food presentations, at least during Sp sessions. During such sessions, the probability that food would be presented in conjunction with the Sp stimulus was approximately equal to the probability that it would not be presented. A diminished correlation would be expected to weaken control over drinking by the Sp stimulus.

The alternation between Sp and Sn sessions may have had the effect of strengthening the Sp-food correlation during Sn sessions, and weakening it during Sp sessions. Thus control over drinking by the Sp stimulus could have been

high early in Sp sessions, but weak late in such sessions. While the data-recording system was not sensitive to possible within-session variations in the level of post-stimulus drinking, informal observations were in accord with the above argument. It was often observed that the first 1 or 2 stimulus presentations during Sp sessions were followed by relatively more drinking than were later presentations.

The preceding suggests that not only the present methods, but also those employed in earlier investigations, may have been inappropriate for the intended purpose. All may have strongly influenced the correlation between Sp stimuli and food presentations.

The above arguments are contrary to Rosenblith's (1970) interpretation of her results as demonstrating an effect of Pavlovian conditioning. In her experiment, food accompanied only one-third of the stimulus presentations, giving rise to a weaker stimulus-food correlation than that of the present experiment. The occurrence of drinking as a CR should, therefore, have been less likely in Rosenblith's than in the present experiment.

An alternative account for Rosenblith's results would attribute the generally high levels of post-stimulus drinking to an effect of outcome predictability such as was observed in Experiment 2. The use of a FR second-order schedule would allow animals to predict component outcomes by means of the reliable sequence in which food and stimuli

were presented. The sequence of outcomes would presumably constitute a less salient stimulus than did the auditory signals of Experiment 2. That could account for the generally slower acquisition of post-stimulus drinking in Rosenblith's experiment than was seen in Experiment 2.

### Experiment 3b

An effective methodology for the comparison of post-Sp and post-Sn drinking may involve single probe trials rather than blocks of Sp presentations. Such a procedure would allow measurement of post-Sp drinking unconfounded by a large decrement in the stimulus-food correlation. That possibility is explored in this experiment.

### Method

Subjects. The experiment was carried out in parallel with Experiment 2, and utilized Subjects 810, 811, and 812 of the control group during Phase 1 of their training.

Procedure. Training was as described in Experiment 2, except that during sessions 16 - 71, a probability gate was set to prevent the delivery of food during 3% of the nominal food presentations. Food "presentations" from which food deliveries were omitted will be referred to as Sp stimulus presentations. They varied in duration as did food presentations. Each consisted of illumination of the white light on the side wall, and ended with a 2.5-sec increase in the intensity of the background white noise. Stimuli presented when food presentations were not scheduled (Sn

stimuli) consisted only of the 2.5-sec increase in noise intensity.

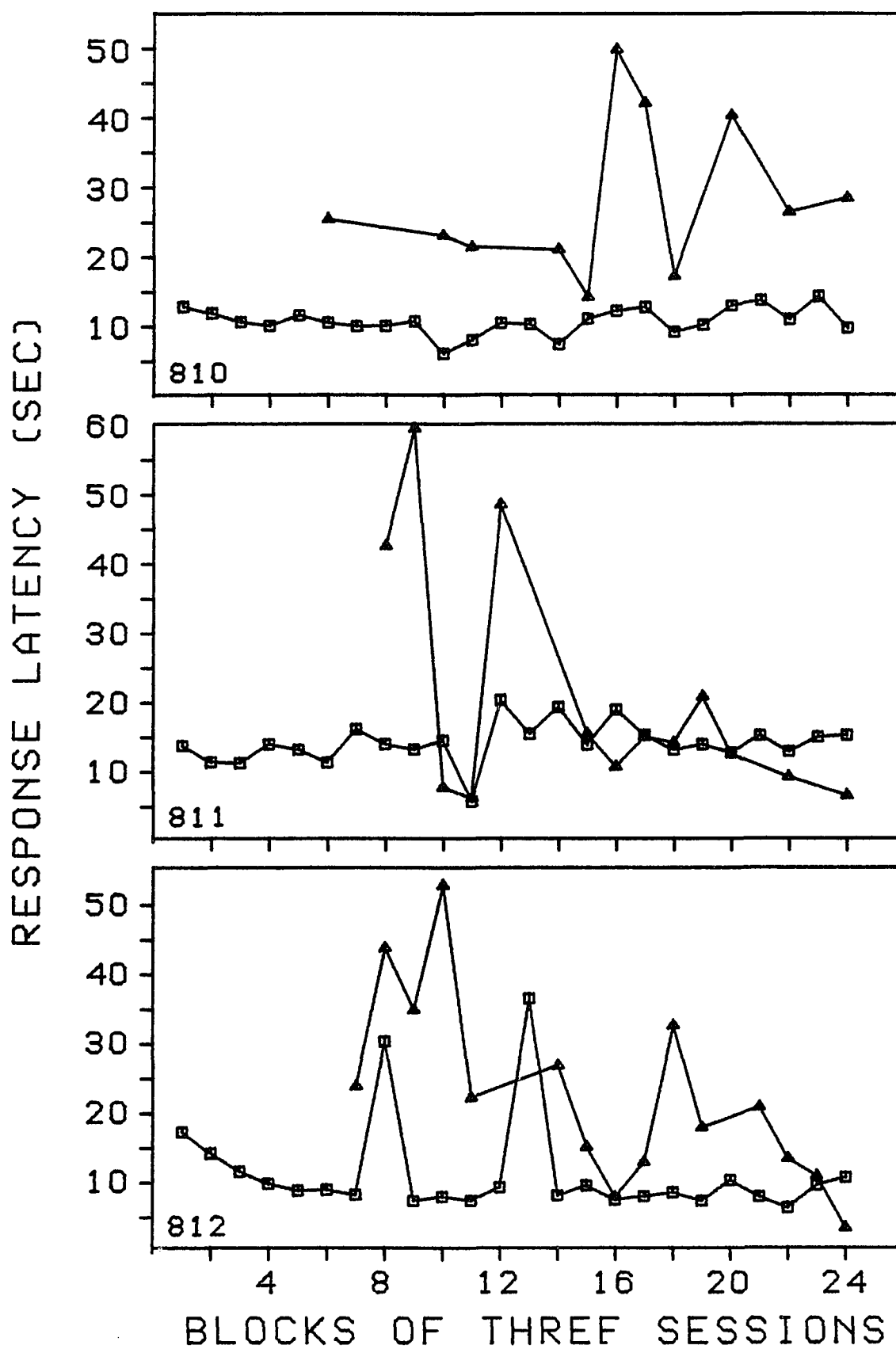
Most sessions contained no more than 1 Sp presentation, many contained none. Subject 810 experienced 4 sessions in which 2 Sp presentations occurred; Subjects 811 and 812, 2 each. Obtained probabilities of replacement of food presentations by Sp stimulus presentations were .03, .03, and .04 for Subjects 810 - 812 respectively. Replacement of food presentations by Sp presentations resulted in the occurrence of food presentation following 47%, rather than 50%, of schedule components for all subjects. The total numbers of Sp presentations were 21, 23, and 27 for Subjects 810, 811, and 812, respectively.

### Results

Post-stimulus lever-press latencies are presented in Figure 48. Post-Sp latencies were clearly longer than were post-Sn latencies for 2 of the 3 subjects (810 and 812). Post-stimulus lever-press indices of curvature are presented in Figure 49. A clear difference can be seen between post-Sp and post-Sn distributions in the data for Subjects 810 and 812. For both of those subjects, post-Sp latencies and lever-press distributions more closely resembled post-food behavior (Appendix B: Preliminary Research) than did post-Sn latencies and distributions. Other aspects of lever-pressing are presented in Appendix B.

Post-Stimulus Lever-Press Latencies

Figure 48. Lever-press latencies were computed separately for post-Sp and post-Sn components for Subjects 810 - 812. Individual subjects are identified by 3-digit numbers. Squares represent post-Sn behavior; triangles, post-Sp behavior. Individual data points represent performance averaged over 3 consecutive sessions.



Indices of Curvature:Post-Stimulus Lever-Pressing

Figure 49. Data represent indices of curvature, as described in Experiment 2, for post-stimulus lever-press distributions of Subjects 810 - 812. Subjects are identified by 3-digit numbers. Squares represent post-Sn behavior; triangles, post-Sp behavior. Individual data points represent performance averaged over 3 consecutive sessions.

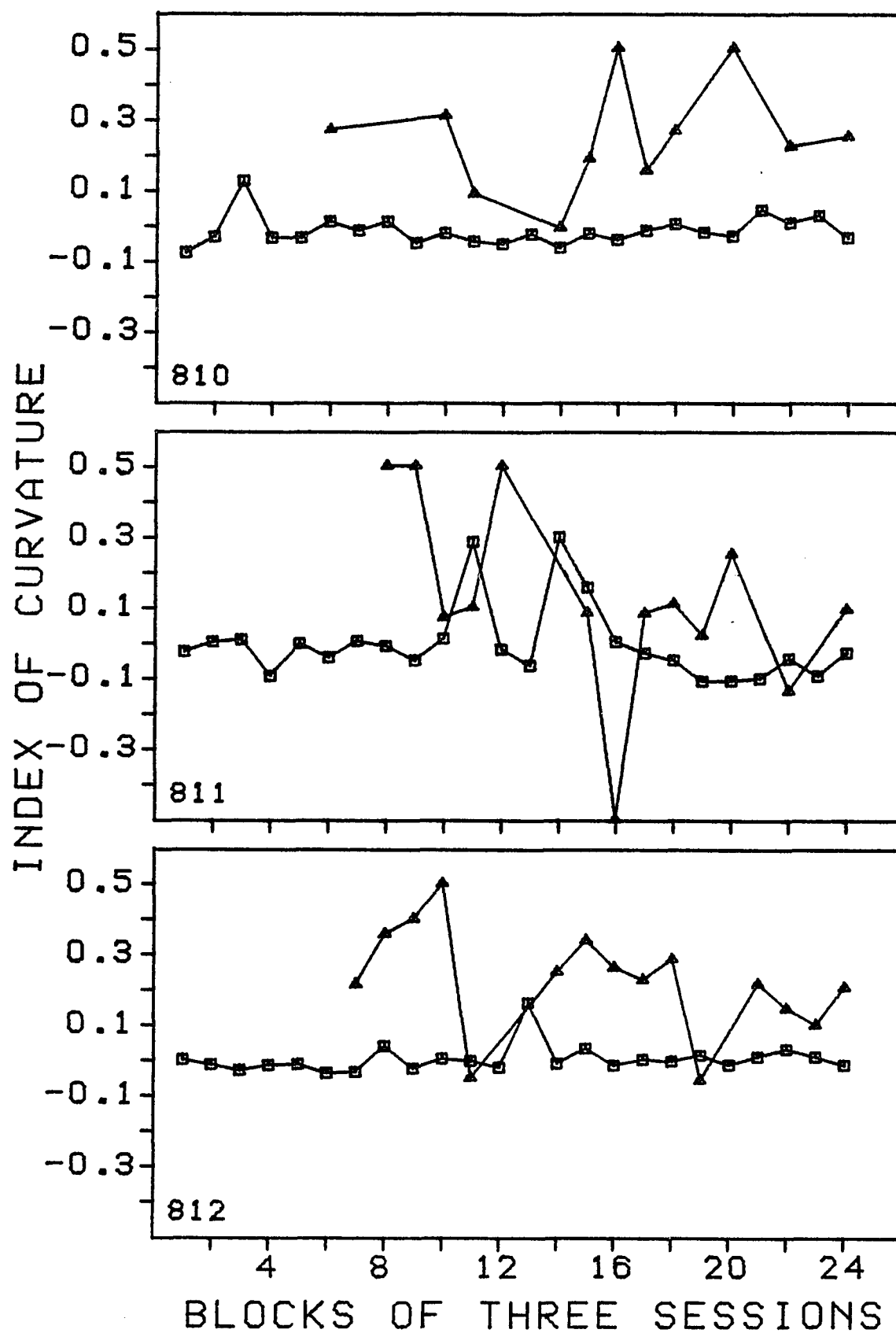




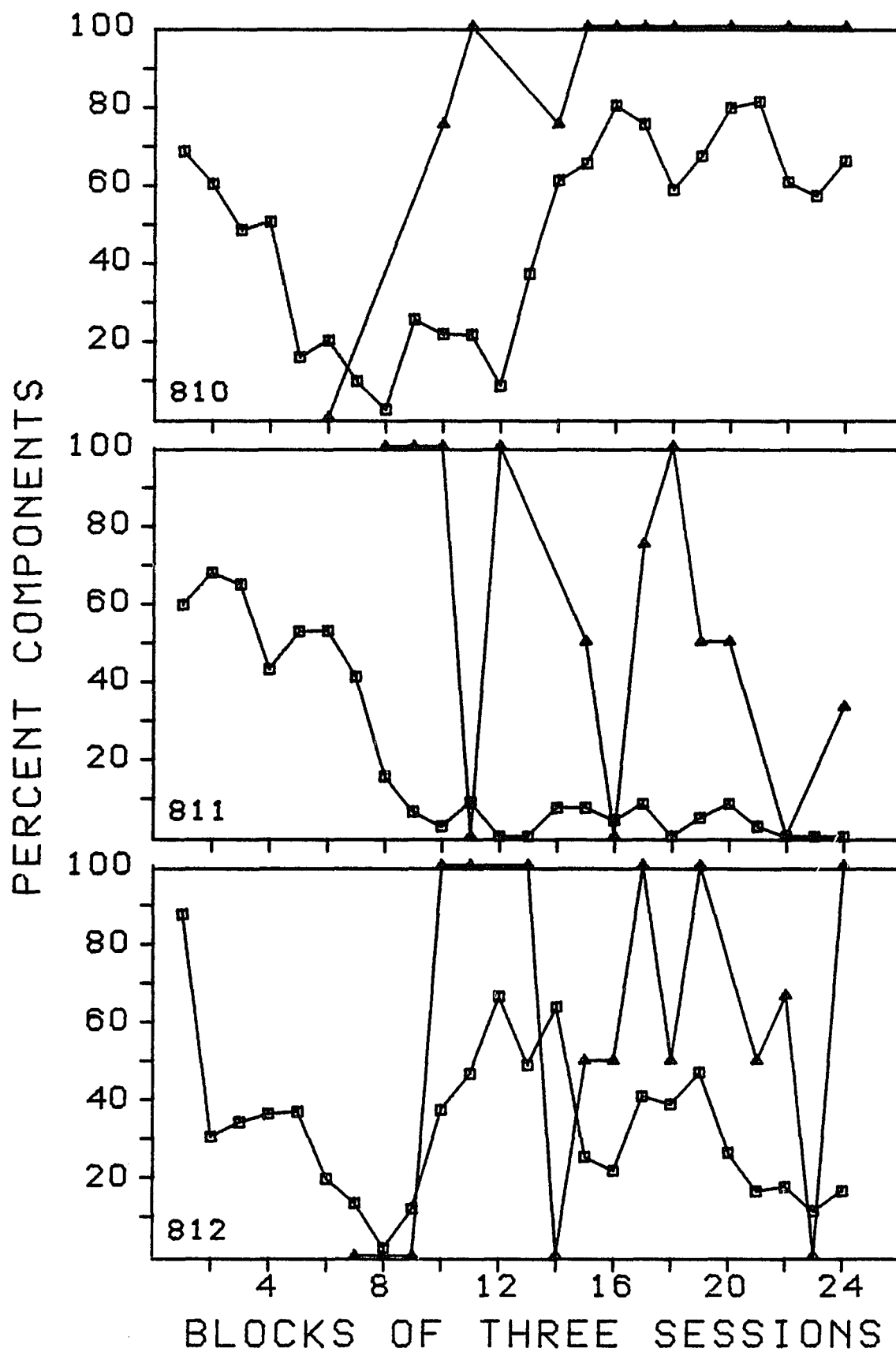
Figure 50 illustrates the percentages of post-Sp and post-Sn components during which drinking occurred. In general, drinking more reliably followed Sp presentations than it did Sn presentations for all 3 subjects. The generally wider fluctuation in the likelihood of post-Sp drinking than in the likelihood of post-Sn drinking is a consequence of the much smaller number of Sp than of Sn presentations, resulting in fewer possible percentage values.

Drinking levels (licks per component in which drinking occurred), broken down by pre- and post-response are presented in Figure 51 (post-stimulus components only). Two aspects of these data are important. First, drinking levels were generally higher during post-Sp components than during post-Sn components. Second, that difference was generally due to higher S1 levels during post-Sp than during post-Sn components. S2 levels did not differ between post-Sp and post-Sn components for 2 of the subjects (810 and 811).

Post-stimulus lick indices of curvature are presented in Figure 52. The IC was clearly more negative during post-Sp than during post-Sn components for Subjects 810 and 811. As with lever-press distributions, the difference in lick distributions was such that post-Sp behavior more closely resembled post-food behavior than did post-Sn behavior.

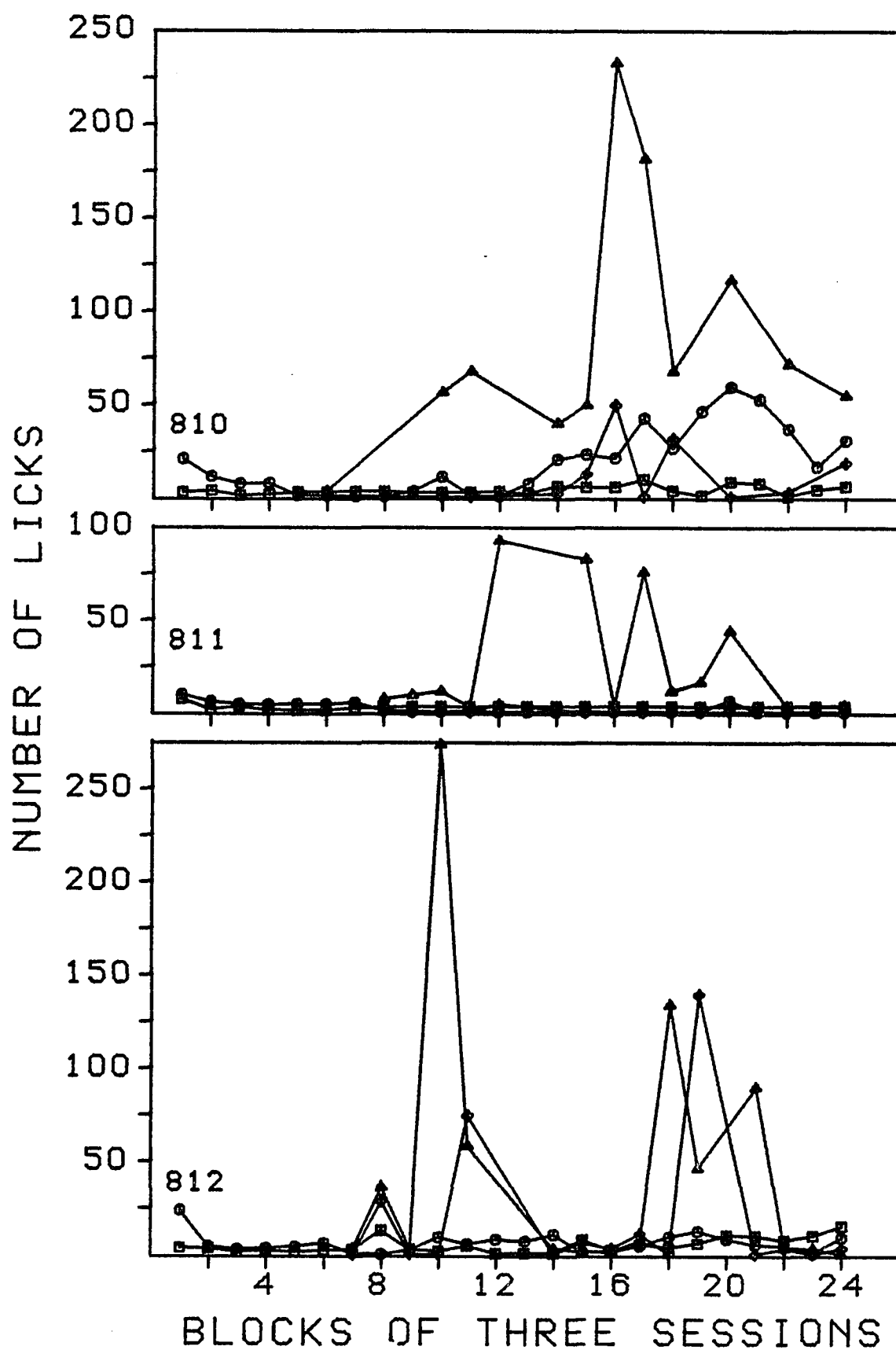
Incidence of Post-Stimulus Drinking

Figure 50. Data represent the percentage of post-stimulus components during which at least one bout of licking (see General Methods) occurred. Individual subjects are identified by 3-digit numbers. Squares represent post-Sn behavior; triangles, post-Sp behavior. Individual data points represent performance averaged over 3 consecutive sessions.



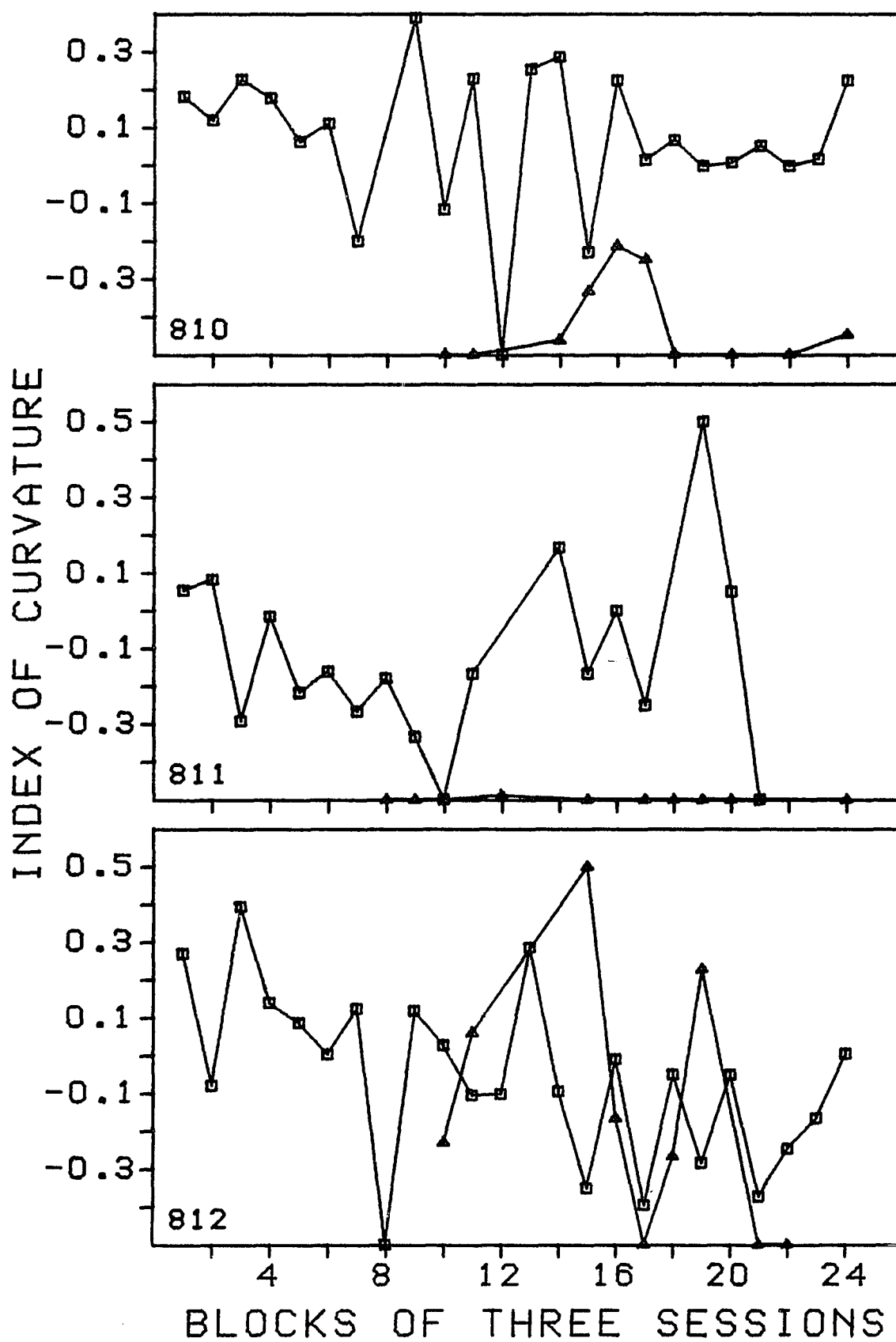
Post-Stimulus Drinking Levels

Figure 51. Data represent licks per component in which drinking occurred, broken down by pre- and post-response licking. Individual subjects are identified by 3-digit numbers. The correspondence between symbols and lick categories is as follows: squares-- Sn1; circles-- Sn2; triangles-- Sp1; and diamonds-- Sp2. Individual data points represent performance averaged over 3 consecutive sessions.



Indices of Curvature:Post-Stimulus Licking

Figure 52. Data represent indices of curvature, as described in Experiment 2, for post-stimulus lick distributions. Individual subjects are identified by 3-digit numbers. Squares represent post-Sn behavior; triangles, post-Sp behavior. Individual data points represent performance averaged over 3 consecutive sessions.



Post-stimulus bout durations are presented in Figure 53. S1 bout durations tended to be longer during post-Sp than during pcst-Sn components, several times approximating typical F1 bout durations.

Post-stimulus lick latencies are presented in Figure 54. In general, post-Sp latencies were shorter than post-Sn latencies. Pcst-Sp latencies were frequently similar to those which followed food presentations (2 - 6 sec); post-Sn latencies were always much longer than post-food latencies.

Other aspects of post-stimulus drinking are described in Appendix F.

### Discussion

The present experiment demonstrated clear post-Sp/post-Sn differences in behavior. Those differences were such that many aspects of post-Sp behavior more closely resembled typical pcst-food behavior (Preliminary Research) than did pcst-Sn behavior. A pcst-Sp/post-Sn difference was reflected in lick and lever-press latencies and distributions, levels and likelihoods of drinking, and in S1 bout durations. These effects have not been previously described.

The general success of the present experiment is presumably due to the maintenance of a high correlation between Sp presentations and food presentations-- 96 - 97% of the light/noise-increase presentations were accompanied by food. The demonstration of reliable post-Sp drinking certainly does not depend upon the concurrent occurrence of



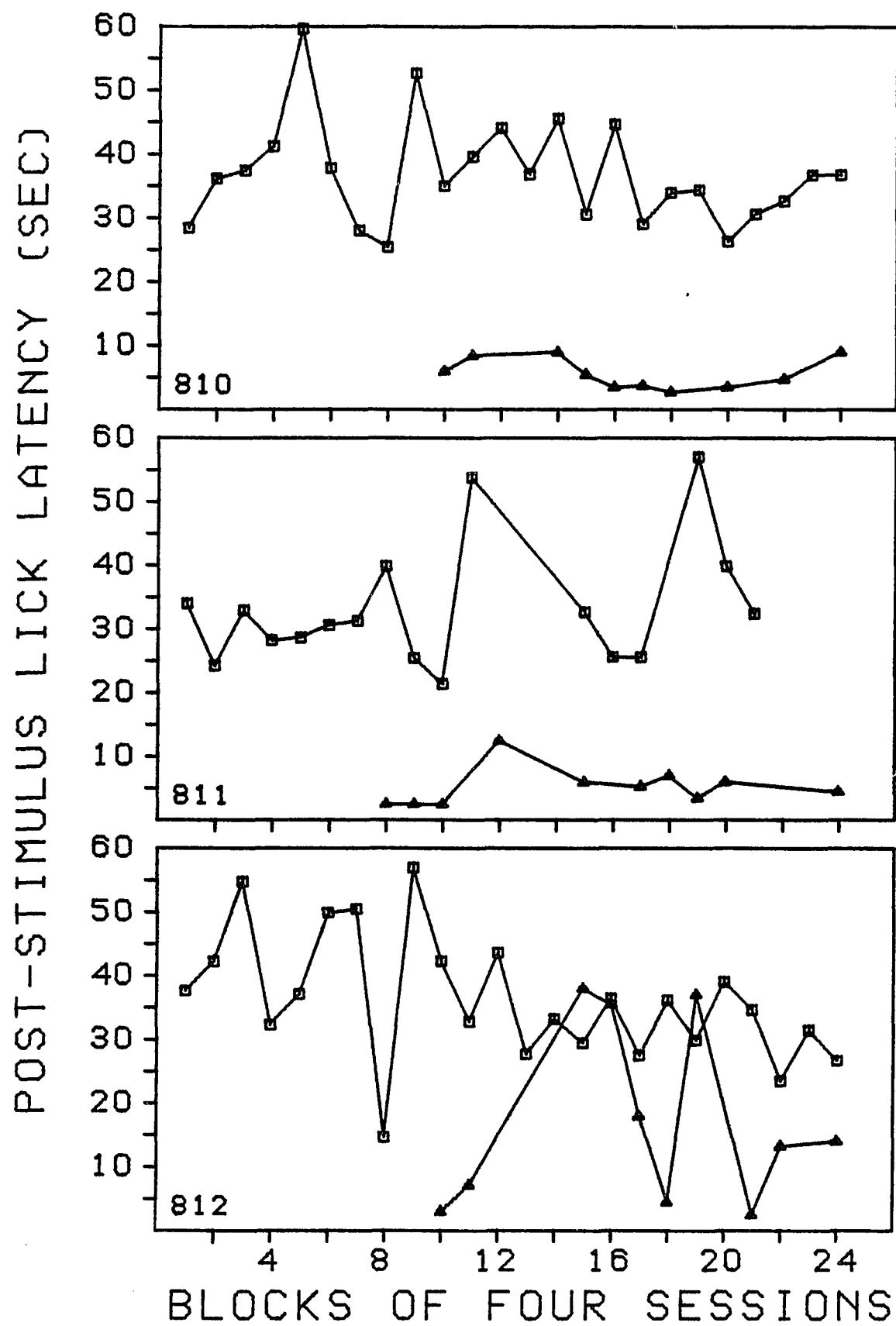
Post-Stimulus Bout Durations

Figure 53. Data represent mean number of licks per post-stimulus bout, broken down according to whether licking occurred before (pre-response) or after (post-response) the onset of lever-pressing within components. Individual subjects are identified by 3-digit numbers. The correspondence between symbols and lick categories is as follows: squares-- Sn1; circles-- Sn2; triangles-- Sp1; and diamonds-- Sp2. Individual data points represent performance averaged over 3 consecutive sessions.

BLOCKS OF THREE SESSIONS

Post-Stimulus Lick Latencies

Figure 54. Data represent post-stimulus lick latencies, computed as described under General Methods. Individual subjects are identified by 3-digit numbers. Squares represent pcst-Sn behavior; triangles, post-Sp behavior. Individual data points represent performance averaged over 3 consecutive sessions.



reliable post-Sn drinking. In previous investigations of the effects of food-paired stimuli during exposure to second-order schedules, the stimulus-food correlation was appreciably weaker. In those experiments, food accompanied, on average, only 50% of the stimulus presentations. A weaker control over drinking as a CR by the Sp CS would therefore be expected-- the CS would have been a less reliable predictor of the food US than was the CS in the present experiment.

### General Discussion of Experiment 3

The presentation of food-paired stimuli during exposure to second-order schedules may affect numerous aspects of behavior. Experiment 3 demonstrates that such stimuli may affect the latency and distribution of operant lever-pressing, and, in some cases, the characteristics of schedule-induced drinking in such a way as to increase the similarity between post-stimulus and post-food behavior.

The generally reliable occurrence of post-Sp drinking during Experiment 3b, despite the general unreliability of post-Sn drinking, was presumably a function of the maintained high correlation between CS and US presentations, thereby permitting maintained control by the CS over a drinking pattern similar to the F1 pattern-- short latency, long bouts of licking.

It would seem that the necessary conditions for obtaining drinking which has the characteristics of a CR are twofold. First, it is necessary to bring about a pause in

lever-pressing. Second, it is necessary to present a stimulus which increases the animal's inclination to drink. A stimulus highly correlated with food presentations is apparently sufficient to fulfill both conditions.

In Phase 1 of Experiment 2, it was observed that, during post-stimulus components, pre-food behavior often more closely resembled post-food behavior than did pre-stimulus behavior. The pre-food signal of Experiment 2, like the Sp stimulus of Experiment 3b, reliably predicted food presentations. It may therefore be described as a Pavlovian CS (delay CS, MacKintosh, 1974), presentations of which were highly correlated with presentations of a food US. Within this framework, it should come as no surprise that the pre-food and pre-stimulus signals of Experiment 2 differed in their control over behavior during post-stimulus components-- lever-press distributions and S1 bout durations more closely resembled post-food behavior during pre-food than during pre-stimulus components. Pre-food lever-press latencies, while often shorter than pre-stimulus latencies, tended to be longer than those exhibited by the control animals (at the end of Phase 1:  $17.5 \pm 7.7$  vs.  $12.7 \pm 3.1$  sec). In several cases also, pre-food lick distributions more closely resembled post-food distributions than did pre-stimulus distributions. There were no cases in which pre-stimulus behavior more closely resembled post-food behavior than pre-food behavior.

All of the above pre-food/pre-stimulus differences observed during Experiment 2 paralleled post-Sp/post-Sn differences observed during Experiment 3b. Additionally, all of the above differences disappeared, as would be expected, during Phase 2 of Experiment 2 when the signal-food correlation was removed.

Considered together, the data of Experiments 2 and 3 suggest that an unanticipated factor differentially affected post-stimulus behavior during the pre-food and pre-stimulus components of Phase 1 in Experiment 2. That factor was the CS-like effect on behavior of the pre-food signal. Thus, pre-food behavior was controlled, not only by the anticipation of food as had been planned, but also by the presentation of a stimulus which controlled post-foodlike behavior. The latter factor presumably did not operate during pre-stimulus components.

### VIII. GENERAL DISCUSSION

It was proposed above (Research Strategy and Hypotheses) that drinking during exposure to second-order schedules could be classified into 4 categories, F1, F2, S1, and S2, which differed with respect both to the types of component in which they occurred (post-food or post-stimulus), and to whether they occurred before or after the onset of lever-pressing within components. Preliminary research demonstrated that F1 drinking differed from the other categories with respect to bout duration-- F1 bouts were much longer. Further, the short bouts of licking characteristic of the other categories typically alternated with bouts of lever-pressing.

Experiment 1 demonstrated that the introduction of a contingency, according to which licking was required, led to an increase in the rate of emission of short lick bouts, but not in the rate of emission of F1 bouts. Further, bout durations were not affected by the contingency, suggesting that the short bout might act as a behavioral unit. Since the short-bout categories of licking were affected by a contingency known to affect terminal behavior (Staddon and Simmelhag, 1971), it was reasoned that they might themselves be classifiable as terminal in nature.



Experiment 2 demonstrated that such is not the case. The manipulations of Experiment 2 led to a clear discrimination between pre-food and pre-stimulus signals with respect to terminal lever-pressing, but not with respect to drinking levels. While more refined analyses detected some effects on drinking, those were both smaller and less reliable than were the effects on lever-pressing. The proposed categorization of short-bout drinking as terminal is, therefore, not well supported. Some of the effects which were observed in that experiment may have been due to CS-controlled effects on pre-food behavior.

It may be more useful at this point to consider the present results in terms of what they suggest about mechanisms by which schedule-induced drinking is controlled, rather than to try to salvage the hypotheses by which the research was directed.

According to one early view (Clark, 1962), schedule-induced drinking was best regarded as a superstitious behavior (Skinner, 1948)-- one which was maintained because it often adventitiously preceded food presentations and was thereby reinforced. Clark (1962) reported that drinking developed most rapidly during exposure to simple VI schedules when a high proportion of the schedule components were of short duration. As he explained matters, the occurrence of a reinforced lever-press was more likely to follow immediately upon the conclusion of an episode of drinking during short components

than during long components (assuming that the duration of the drinking episode remains constant). The number of opportunities for drinking to be so reinforced would then be directly related to the proportion of brief components comprising the VI schedule.

While the conceptualization of schedule-induced drinking as a superstitious behavior has not been widely accepted (Staddon, 1977), it is useful to consider the idea in light of the results of Experiments 1 and 2. First, since it has been demonstrated that drinking is sensitive to an explicit contingency, there is no reason to suppose that drinking would not be sensitive to adventitious reinforcement. Second, the effect of a contingency can be to increase the level of drinking. This certainly could take the form of an increase in the rate of acquisition of schedule-induced drinking. Third, the effect of the contingency of Experiment 1 was to increase the rate at which short lick bouts were emitted, possibly because short bouts were typically more contiguous to reinforcing events than were long bouts. Whether a contingency would always act to increase the rate of emission of short bouts, or whether long-bout drinking could be similarly affected if conditions were right, has yet to be determined. It is clear at any rate that schedule-induced drinking is sensitive to its relationship to reinforcing events.

The results of Experiment 2, however, do not agree with the proposition that drinking is typically maintained by its relationship to reinforcing events. It can be assumed that lever-pressing is so maintained, and lever-pressing was found to be sensitive to the types of component outcomes which were signalled. Drinking, however, was relatively insensitive to component outcomes. If one were to argue that drinking is maintained by adventitious reinforcement, then one would have to expect that drinking would have responded to the signals in the same manner as did lever-pressing. That it did not suggests that, while adventitious reinforcement may operate under some conditions, it does not do so under the full range of conditions which may give rise to schedule-induced drinking. It, therefore, does not provide a generally useful account for schedule-induced drinking.

A widely used alternative account for the occurrence of schedule-induced drinking relies on the observation that drinking frequently follows eating under ad lib. conditions. In this view, drinking is regarded as analogous to an unconditioned response to some as yet unidentified stimulus generated internally during the act of eating.

It must be assumed that the internal stimulus generated by the consumption of a single 45-mg food pellet is relatively weak. Drinking typically does not follow the ingestion of each pellet, either under free-feeding conditions (Kissileff, 1969; Letter, Woods, and Vasselli,

1973), or when food can be obtained at a high rate by lever-pressing, as during continuous reinforcement (Falk, 1967). Instead, it is usually observed that drinking episodes occur only after the ingestion of a relatively large number of food pellets in both cases.

It is reasonable to assume that a variety of conflicting response tendencies are present at the start of training with any reinforcement schedule-- exploratory tendencies, grooming tendencies, and the tendency to engage in terminal behavior, as well as the tendency to drink. If one is willing to assume that the eating-produced stimulus event which controls drinking is relatively weak, then one can account for the gradual emergence of schedule-induced drinking. The occurrence of excessive drinking would require that competing, and perhaps stronger, response tendencies be eliminated. Exploratory tendencies would gradually weaken as habituation to extraneous stimuli occurred. When food is presented periodically, the animal could learn that food occurs at some times, but not immediately after a previous food delivery (Staddon, 1977). Thus, the tendency to engage in terminal behavior could increasingly be inhibited during the immediate post-food period. As competing response tendencies were gradually eliminated, food-controlled drinking could appear, its magnitude being inversely related to the strengths of competing response tendencies during the post-food period.

That the sort of drinking typically observed during exposure to simple schedules may depend upon a signal generated during the act of eating is suggested by the data of Experiment 3. A relatively low correlation between stimulus and food presentations, while it did give rise to post-stimulus pauses in lever-pressing, did not give rise to conditioned drinking, even though at a molar level drinking was a highly probable behavior during experimental sessions. It was only after food presentations or after presentations of a stimulus highly correlated with food presentations that long lick bouts occurred.

While drinking during exposure to second-order schedules may be controlled under some conditions by Pavlovian and/or operant contingencies, it is clear such drinking is also sensitive to other factors. One previously unidentified factor which may be of importance is the predictability of component outcomes. Outcomes were perfectly predictable for the experimental subjects during Phase 1 of Experiment 2-- 8 of the 9 drank reliably during post-stimulus components. Outcomes were relatively unpredictable for the control subjects-- 1 of 3 drank reliably during post-stimulus components, and then only after extensive experience. Further, when outcomes were made unpredictable for the experimental subjects in that experiment, post-stimulus drinking was disrupted in 7 of the 9 cases.

Rosenblith (1970) obtained reliable post-stimulus drinking. As discussed in conjunction with Experiment 3a, that result might be more readily interpreted as a result of the predictability of component outcomes than as a result of Pavlovian conditioning. Corfield-Sumner, et al (1977) observed very little post-stimulus drinking among subjects exposed to a response-independent second-order schedule in which component outcomes were unpredictable. By contrast, post-stimulus drinking reliably occurred among all 3 subjects exposed to a response-independent schedule when the component outcomes were predictable during Experiment 2.

It must be pointed out, however, that outcome predictability is neither a necessary nor a sufficient condition for obtaining post-stimulus drinking. Corfield-Sumner, et al (1977) obtained reliable post-stimulus drinking from animals exposed to a response-dependent condition in which the sequence of component outcomes was unpredictable. In Experiment 2 of this dissertation, post-stimulus drinking levels did not recover during Phase 3 when outcomes were again made predictable. Allen and Porter (1977) and Porter, et al (1975) failed to obtain reliable post-stimulus drinking when using the same schedule used earlier by Rosenblith (1970), which presumably made outcomes predictable. The study by Porter et al was, however, similar to Phase 3 of Experiment 2, in that animals first received extended training with unpredictable outcomes.

Based on the foregoing, it would seem that outcome predictability must achieve whatever effect it may have through an interaction with other factors. The mechanism by which that effect is achieved, and the factors with which predictability interacts, are topics requiring further research.

There have been suggestions in the literature that the short-bout sort of licking which is commonly observed during post-stimulus components is somehow maintained in conjunction with lever-pressing (Allen and Porter, 1977). The present data do not support that view. In Experiment 2, levels of drinking were independent both of the occurrence and of the rate of lever-pressing when the latter was required. Thus, while drinking can be brought under the control of factors which control lever-pressing (Experiment 1), it is not generally controlled by those factors.

The present data clearly contribute to the understanding of schedule-induced drinking. A new factor, predictability of environmental events, has been advanced as a candidate for further study. Evidence has been presented that some drinking may be elicited and some may be brought under instrumental control. Drinking apparently occurs as a behavior in its own right, and not merely as an element of a behavioral chain.

The fact remains, however, that we do not yet know the specific combination of factors which gives rise to schedule-induced drinking. We do not know with certainty

whether drinking induced by exposure to second-order schedules is of a single or a multiplicity of types. Further, we do not know why, under seemingly identical conditions, some animals might consistently drink during post-stimulus components while others might do so only rarely, witness Subject 803 of Experiment 2. As was true before the present research began, these facts remain to be elucidated.



**LIST OF REFERENCES**

- Allen, J. D. and Kenshalo, D. R., Jr. Schedule-induced drinking as a function of interreinforcement interval in the rhesus monkey. Journal of the Experimental Analysis of Behavior, 1976, 26, 257-267.
- Allen, J. D. and Porter, J. H. Demonstration of behavioral contrast with adjunctive drinking. Physiology and Behavior, 1975, 15, 511-515.
- Allen, J. D. and Porter, J. H. Sources of control over schedule-induced drinking produced by second-order schedules of reinforcement. Physiology and Behavior, 1977, 18, 853-863.
- Allen, J. D., Porter, J. H., and Arazie, R. Schedule-induced drinking as a function of percentage reinforcement. Journal of the Experimental Analysis of Behavior, 1975, 23, 223-232.
- Burks, C. D. and Fisher, A. E. Anticholinergic blockade of schedule-induced polydipsia. Physiology and Behavior, 1970, 5, 635-640.
- Cantor, M. E. and Wilson, J. F. Polydipsia induced by a schedule of brain stimulation reinforcement. Learning and Motivation, 1978, 9, 428-445.
- Clark, F. H. Some observations on the adventitious reinforcement of drinking under food reinforcement. Journal of the Experimental Analysis of Behavior, 1962, 5, 61-63.
- Clark, L. K. Schedule-induced drinking in a second-order schedule: Effects of pairing the stimulus with reinforcement termination. Unpublished Master's paper, 1978.
- Cohen, I. I., and Mendelson, J. Schedule-induced drinking with food, but not ICS, reinforcement. Behavioral Biology, 1974, 12, 21-29.
- Cope, C. L., Sanger, D. J., and Blackman, D. E. Intragastric water and the acquisition of schedule-induced drinking. Behavioral Biology, 1976, 17, 267-270.
- Corfield-Sumner, P. K., Blackman, D. E., and Stainer, G. Polydipsia induced in rats by second-order schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1977, 27, 265-273.
- Couch, J. V. Reinforcement magnitude and polydipsia: A re-examination. The Psychological Record, 1974, 24, 559-562.

- Falk, J. L. Production of polydipsia in normal rats by an intermittent food schedule. Science, 1961, 133, 195-196.
- Falk, J. L. The motivational properties of schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1966, 9, 19-25. (a)
- Falk, J. L. Analysis of water and NaCl solution acceptance by schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1966, 9, 111-118. (b)
- Falk, J. L. Control of schedule-induced polydipsia: Type, size and spacing of meals. Journal of the Experimental Analysis of Behavior, 1967, 10, 199-206.
- Falk, J. L. Conditions producing psychogenic polydipsia in animals. Annals Of the New York Academy of Sciences, 1969, 157, 569-593.
- Falk, J. L. The nature and determinants of adjunctive behavior. Physiology and Behavior, 1971, 6, 577-588.
- Falk, J. L. The origin and functions of adjunctive behavior. Animal Learning and Behavior, 1977, 5, 325-335.
- Fitzsimons, J. T. and LeMagnen, J. Eating as a regulatory control of drinking in the rat. Journal of Comparative and Physiological Psychology, 1969, 267, 273-283.
- Flory, R. K. The control of schedule-induced polydipsia: Frequency and magnitude of reinforcement. Learning and Motivation, 1971, 2, 215-227.
- Flory, R. K. and Lickfett, G. G. Effects of lick-contingent timeout on schedule-induced polydipsia. Journal of the Experimental Analysis of Behavior, 1974, 21, 45-55.
- Freed, E. X. and Hymowitz, N. Effects of schedule, percent body weight, and magnitude of reinforcer on acquisition of schedule-induced polydipsia. Psychological Reports, 1972, 31, 95-101.
- Fry, W., Kelleher, R. T., and Cook, I. A mathematical index of performance on fixed-interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 1960, 3, 193-199.

- Hawkins, T. D., Schrot, J. F., Githens, S. H., and Everett, P. B. Schedule-induced polydipsia: An analysis of water and alcohol ingestion. In R. M. Gilbert and J. D. Keehn (Eds.), Schedule effects: Drugs, drinking, and aggression. Toronto: University of Toronto Press, 1972.
- Huston, J. P. and DeSisto, M. J. Interspecies aggression during fixed-ratio hypothalamic self-stimulation in rats. Physiology and Behavior, 1971, 7, 353-357.
- Kachanoff, R., Leveille, R., McLelland, J. P., and Wagner, M. J. Schedule-induced behavior in humans. Physiology and Behavior, 1973, 11, 395-398.
- Kelleher, R. T. Conditioned reinforcement in second-order schedules. Journal of the Experimental Analysis of Behavior, 1966, 9, 475-485.
- Kelly, J. F. and Hake, D. F. An extinction-induced increase in an aggressive response with humans. Journal of the Experimental Analysis of Behavior, 1970, 14, 153-164.
- Kerlinger, F. N. and Pedhazur, E. J. Multiple regression in behavioral research. New York: Holt, Rinehart, and Winston, 1973.
- Killeen, P. On the temporal control of behavior. Psychological Review, 1975, 82, 89-115.
- King, C. D. and Schaeffer, R. W. Developmental analysis of schedule-induced polydipsia. Psychological Reports, 1973, 32, 1087-1095.
- Kissileff, H. R. Food associated drinking in the rat. Journal of Comparative and Physiological Psychology, 1969, 67, 284-300.
- Lashley, R. L. and Rossellini, R. A. Modulation of schedule-induced polydipsia by Pavlovian conditioned states. Physiology and Behavior, 1980, 24, 411-414.
- Levitsky, D. and Collier, G. Schedule-induced wheel-running. Physiology and Behavior, 1968, 3, 571-573.
- Looney, T. A. and Cohen, P. S. Pictorial target control of schedule-induced attack in white carneaux pigeons. Journal of the Experimental Analysis of Behavior, 1974, 21, 571-584.

- Lotter, F. C., Woods, S. C., and Vasselli, J. R. Schedule-induced polydipsia: An artifact. Journal of Comparative and Physiological Psychology, 1973, 83, 478-484.
- MacKintosh, N. J. The psychology of animal learning. London: Academic Press, 1974.
- Magyar, R. L. and Malaqodi, E. F. Measurement and development of schedule-induced drinking in pigeons. Physiology and Behavior, 1980, 25, 245-251.
- McFarland, D. J. Hunger, thirst, and displacement pecking in the barbery dove. Animal Behaviour, 1965, 13, 293-300.
- Millenson, J. R. Principles of behavioral analysis. New York: MacMillan, 1967.
- Millenson, J. R., Allen, R. B., and Pinker, S. Adjunctive drinking during variable and random-interval food reinforcement schedules. Animal Learning and Behavior, 1977, 5, 285-290.
- Moran, G. and Rudolph, R. L. Some effects of lick-contingent delays on the development of schedule-induced polydipsia. Learning and Motivation, 1980, 11, 366-385.
- Csborne, S. R. A quantitative analysis of the effects of amount of reinforcement on two response classes. Journal of Experimental Psychology: Animal Behavior Processes, 1978, 4, 297-317.
- Falfai, T., Kutscher, C. L., and Symons, J. P. Schedule-induced polydipsia in the mouse. Physiology and Behavior, 1971, 6, 461-462.
- Pavlov, I. P. Conditioned reflexes. (G. Anrep, translator) Oxford: Oxford University Press, 1927.
- Porter, J. H., Arazie, R., Holbrock, J. W., Cheek, M. S., and Allen, J. D. Effects of variable and fixed second-order schedules on schedule-induced polydipsia in the rat. Physiology and Behavior, 1975, 14, 143-149.
- Porter, J. H. and Bryant, W. E., Jr. Acquisition of schedule-induced polydipsia in the mongolian gerbil. Physiology and Behavior, 1978, 21, 825-827.
- Porter, J. H., Sozer, N. N., and Moeschl, T. P. Schedule-induced polydipsia in the guinea pig. Physiology and Behavior, 1977, 19, 573-575.

- Rashotte, M. F., Katz, H. N., Griffith, R. W., and Wright, A. C. Vocalizations of white carneaux pigeons during experiments on schedule-induced aggression. Journal of the Experimental Analysis of Behavior, 1975, 23, 285-292.
- Reberg, R. Reinforcing the occurrence or nonoccurrence of interim drinking. Animal Learning and Behavior, 1980, 8, 120-128.
- Rosenblith, J. Z. Polydipsia induced in the rat by a second-order schedule. Journal of the Experimental Analysis of Behavior, 1970, 14, 139-144.
- Schaeffer, R. W. and Salzberg, C. L. Licking response distributions associated with the acquisition of schedule-induced polydipsia. Bulletin of the Psychonomic Society, 1973, 2, 205-207.
- Segal, E. F. and Deadwyler, S. A. Determinants of polydipsia: VI. Taste of the drinking solution on DRL. Psychonomic Science, 1965, 3, 101-102.
- Shanab, M. E. and Peterson, J. L. Polydipsia in the pigeon. Psychonomic Science, 1969, 15, 51-52.
- Skinner, B. F. The behavior of organisms. New York: Appleton-Century-Crofts, 1938.
- Skinner, B. F. "Superstition" in the pigeon. Journal of Experimental Psychology, 1948, 38, 168-172.
- Staddon, J. E. R. Schedule-induced behavior. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of operant behavior. Englewood Cliffs, NJ: Prentice-Hall, 1977.
- Staddon, J. E. R. and Ayres, S. I. Sequential and temporal properties of behavior induced by a periodic schedule of food delivery. Behaviour, 1975, 24, 26-49.
- Staddon, J. E. R. and Simmelhag, V. L. The "superstition" experiment: A re-examination of its implications for the principles of adaptive behavior. Psychological Review, 1971, 78, 3-43.
- Stein, L. Excessive drinking in the rat: Superstition or thirst? Journal of Comparative and Physiological Psychology, 1964, 58, 237-242.

- Stricker, E. M. and Adair, E. R. Body fluid balance, taste, and postprandial factors in schedule-induced polydipsia. Journal of Comparative and Physiological Psychology, 1966, 62, 449-454.
- Stubbs, D. A. Second-order schedules and the problem of conditioned reinforcement. Journal of the Experimental Analysis of Behavior, 1971, 16, 289-313.
- Taylor, D. B. and Lester, D. Schedule-induced nitrogen "drinking" in the rat. Psychonomic Science, 1969, 15, 17-18.
- Tukey, J. W. Exploratory data analysis. Reading, MA: Addison-Wesley, 1977.
- Wayner, M. J. Specificity of behavioral regulation. Physiology and Behavior, 1974, 12, 851-869.
- Wayner, M. J. and Greenberg, I. Effects of septal lesions on palatability modulation of schedule-induced polydipsia. Physiology and Behavior, 1972, 9, 663-665.

## APPENDICES

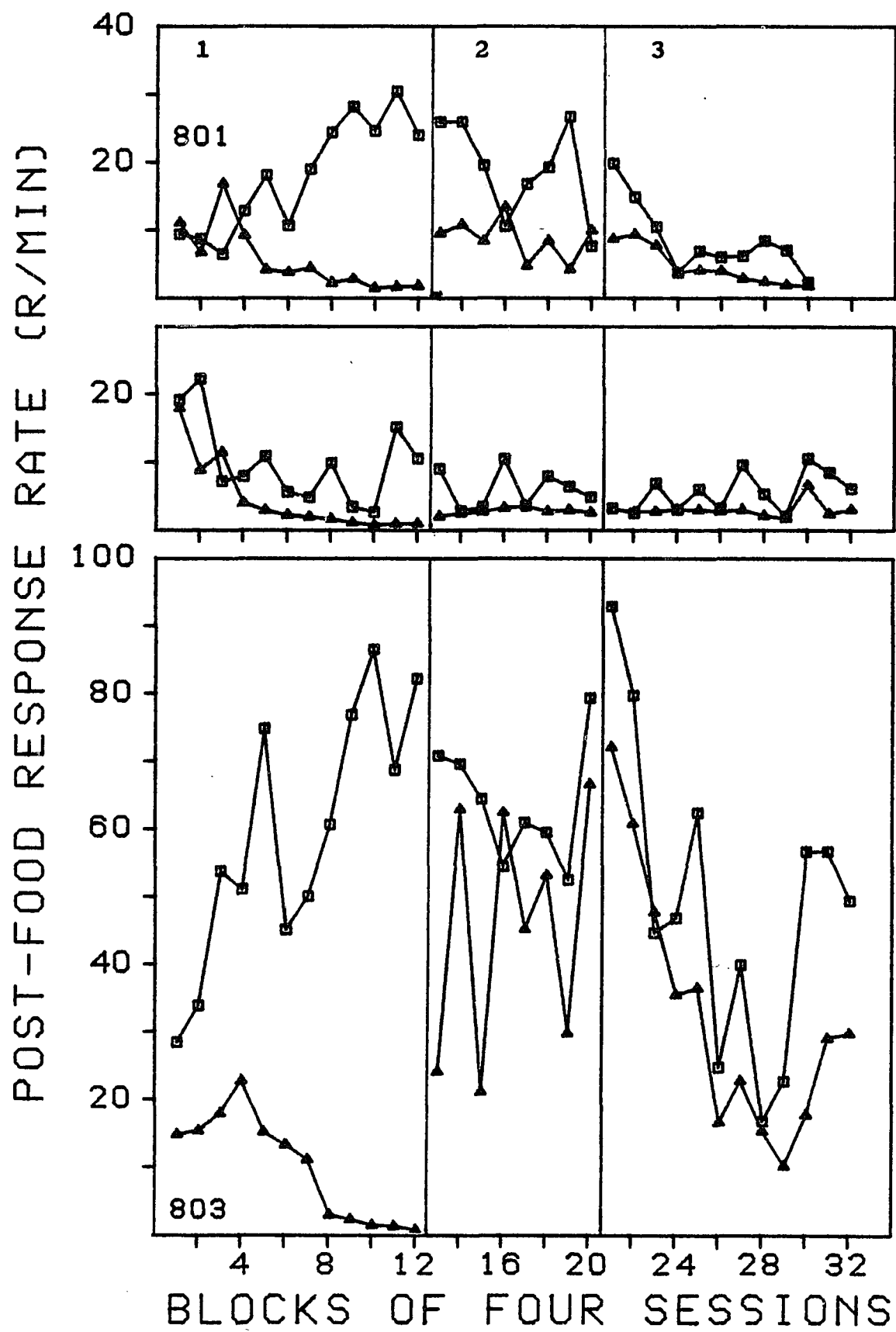


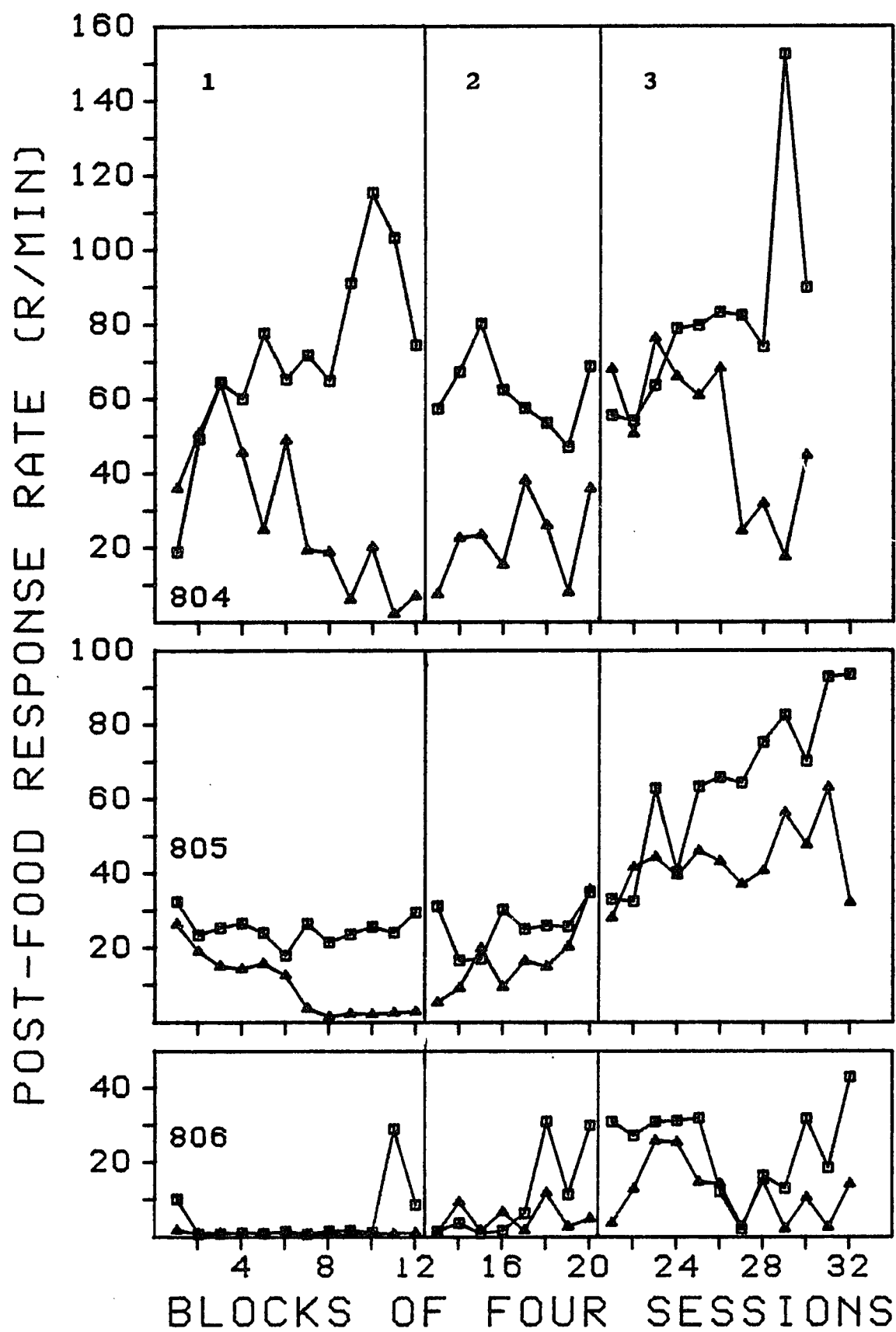
A. ADDITIONAL RESULTS OF EXPERIMENT 2

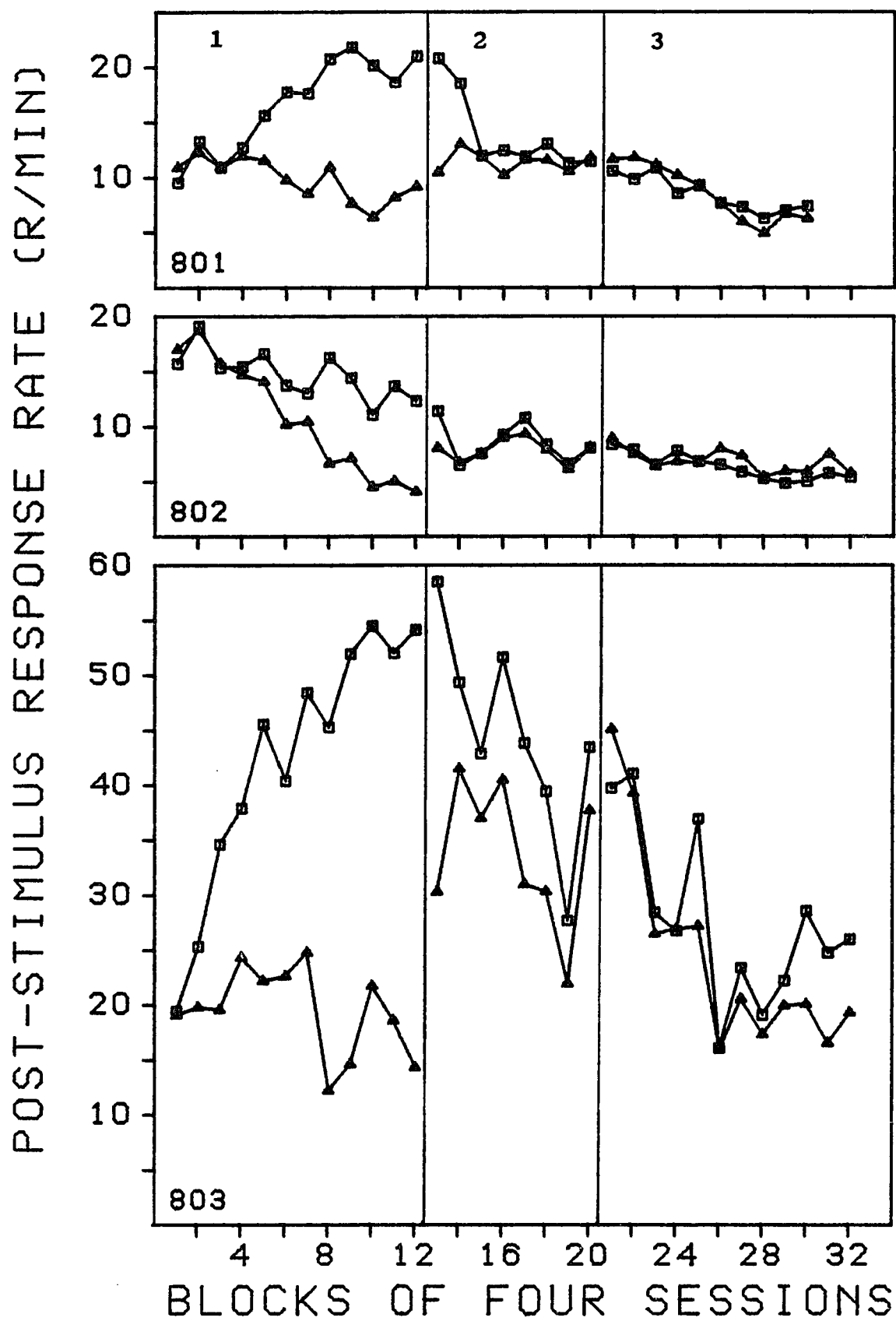
### Lever-Press Rates

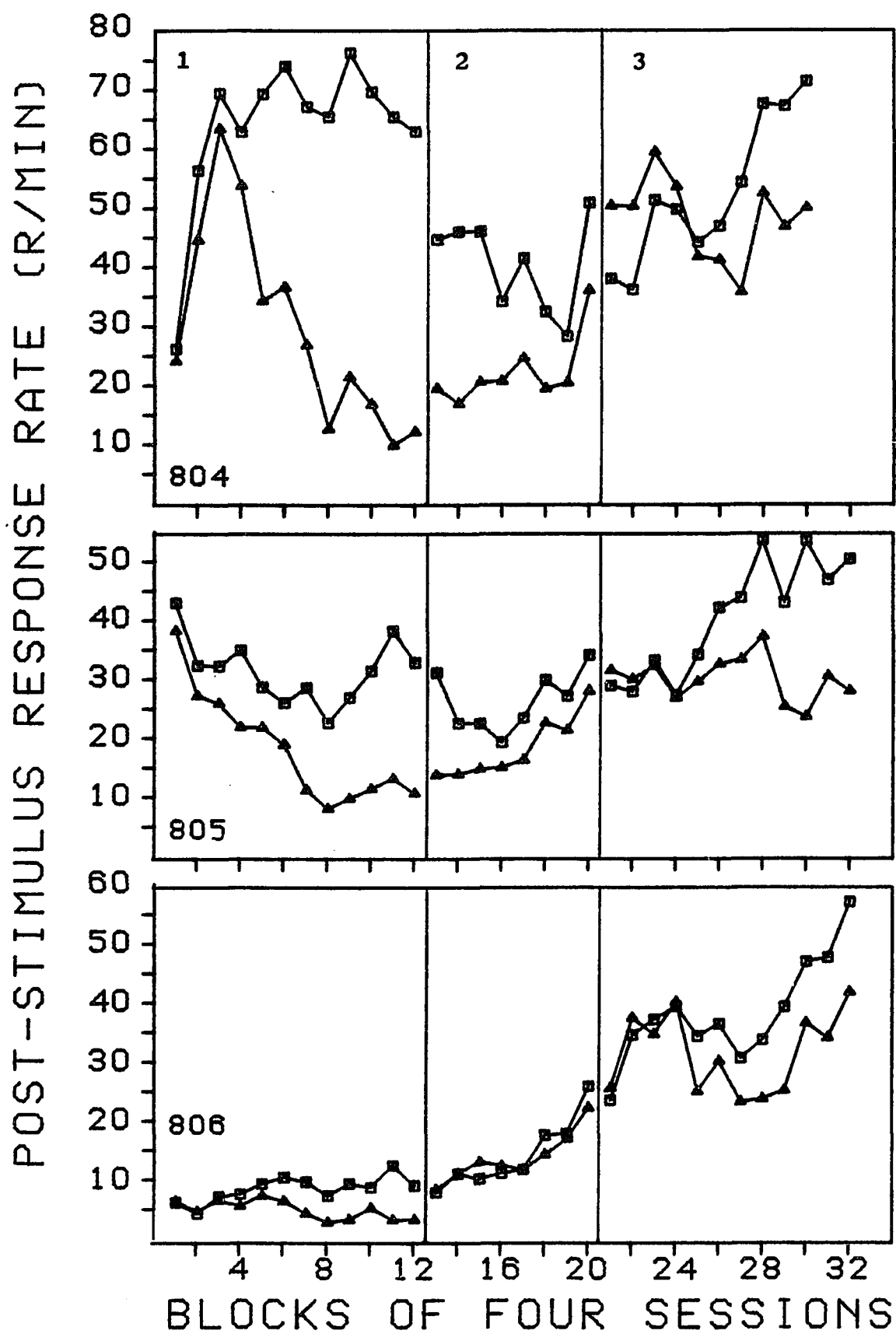
Figures 55 - 58. Data represent running lever-press rates, computed as described under General Methods, for experimental subjects in the response-dependent condition (801 - 806). Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations, while triangles represent behavior in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.

By the conclusion of Phase 1, pre-food rates consistently exceeded pre-stimulus rates for all subjects during both post-food (Figures 55 and 56) and post-stimulus (Figures 57 and 58) components. The pre-food/pre-stimulus rate difference diminished during Phase 2 for all subjects and recovered to some extent during Phase 3, but at a lower rate than did acquisition of the original discrimination. Average post-stimulus rates were generally comparable to average post-food rates, as was typically observed during preliminary research.









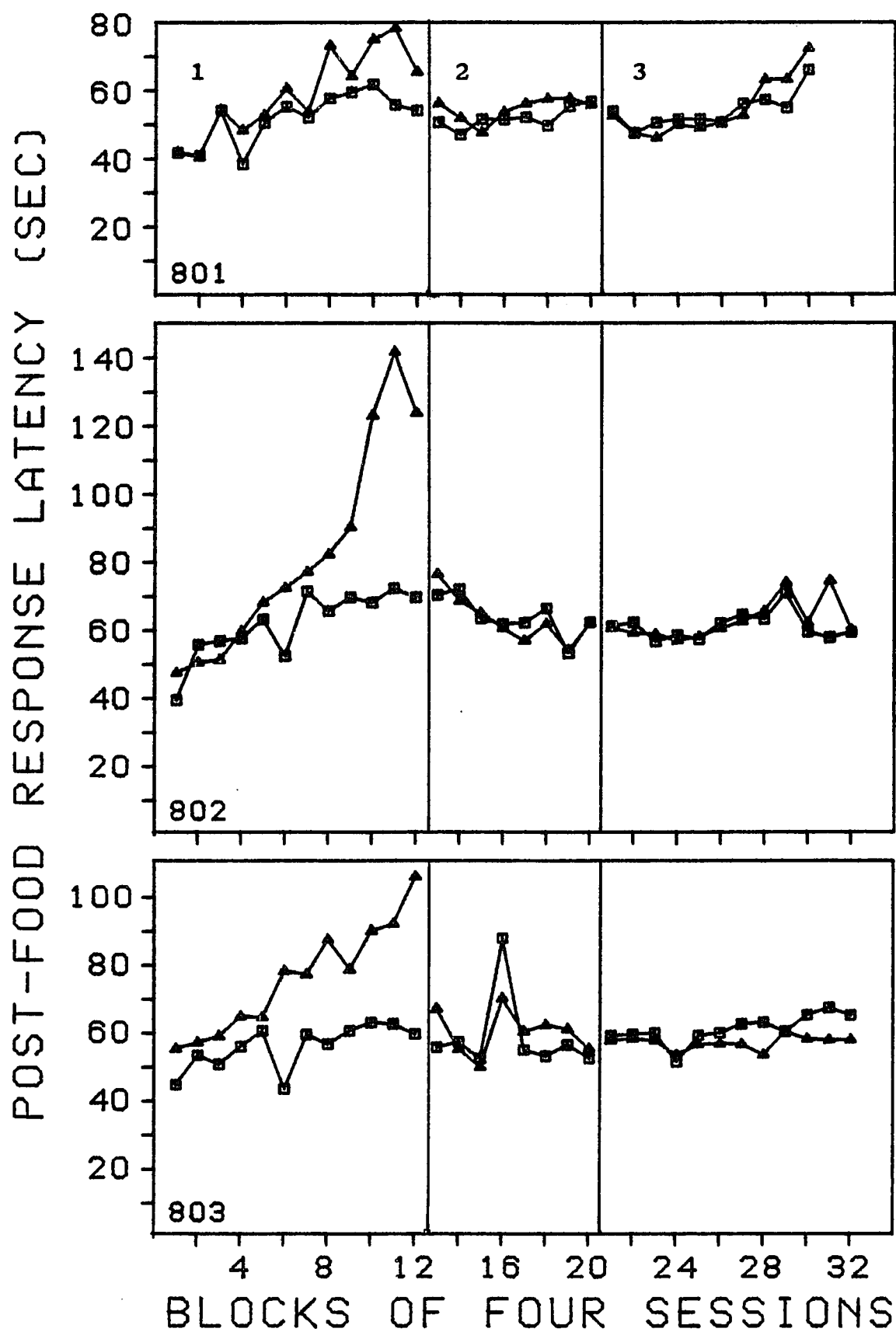
### Lever-Press Latencies

Figures 59 - 64. Data represent lever-press latencies during post-food (Figures 59 - 61) and post-stimulus (Figures 62 - 64) for all subjects for which lever-pressing was required. Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. For experimental animals (801 - 806) during Phases 1 and 3, and for control animals (811 and 812) during Phase 2, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations, while triangles represent behavior in the presence of the signal previously correlated with stimulus presentations. Signals were not presented to control animals during Phase 1. Squares represent average post-food behavior for control animals in Figure 61, and average post-stimulus behavior in Figure 64 during Phase 1 for those animals. For Subject 810, squares during Phase 2 represent behavior in the presence of the tone, while triangles represent behavior in the presence of the repetitive click, neither of which was correlated with component outcomes for that animal. Individual data points represent performance averaged over 4 consecutive sessions.

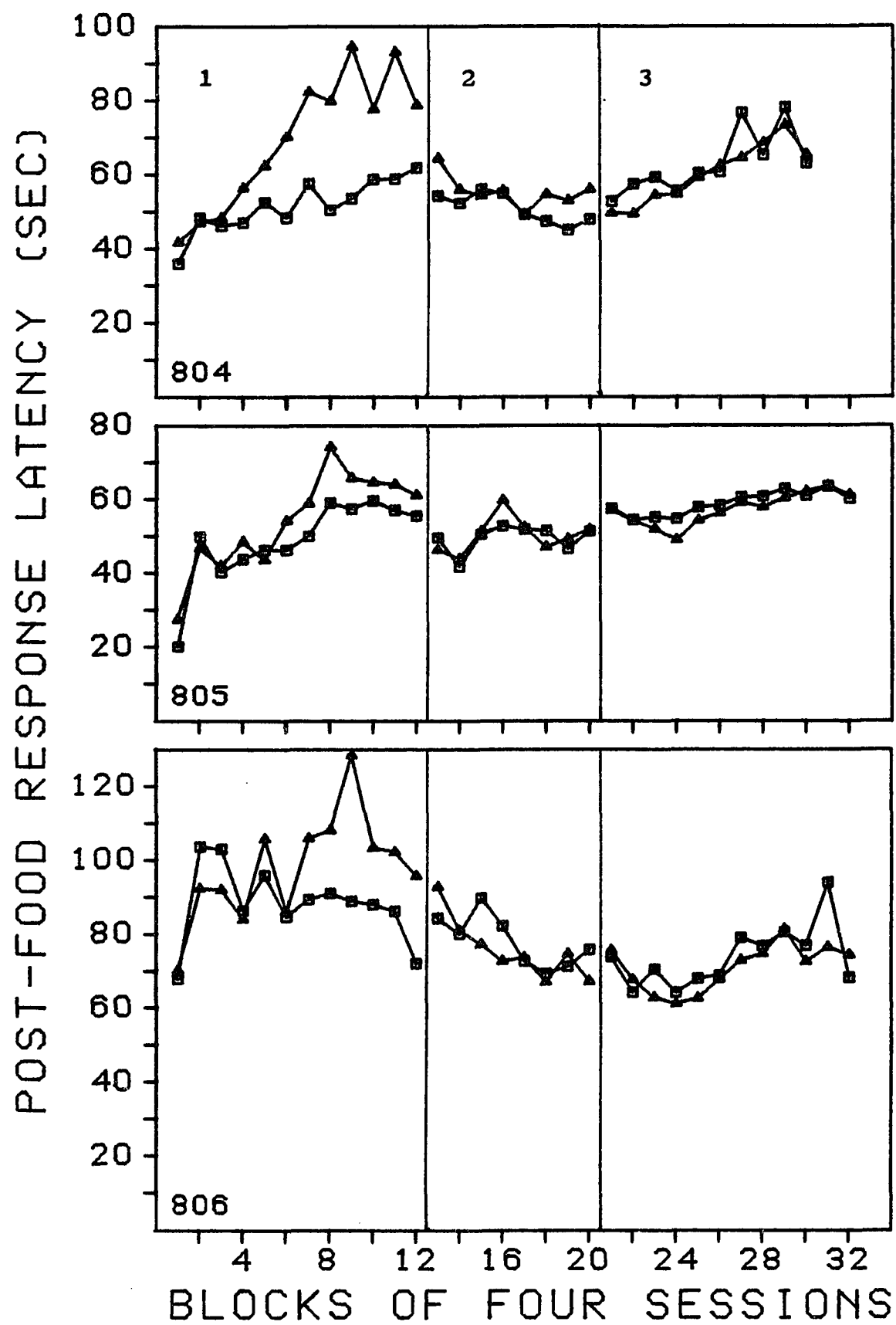
During post-food components at the conclusion of Phase 1 (Figures 59 and 60), pre-food (FF) latencies were consistently shorter than pre-stimulus (SF) latencies among experimental animals. That difference disappeared during Phase 2 and generally did not recover during Phase 3. Phase 1 post-food latencies among control animals (Figure 61) were generally much closer to pre-food than to pre-stimulus latencies among the experimental animals. The Phase 2 latencies of the control animals did not reflect a consistent pre-food/pre-stimulus difference.

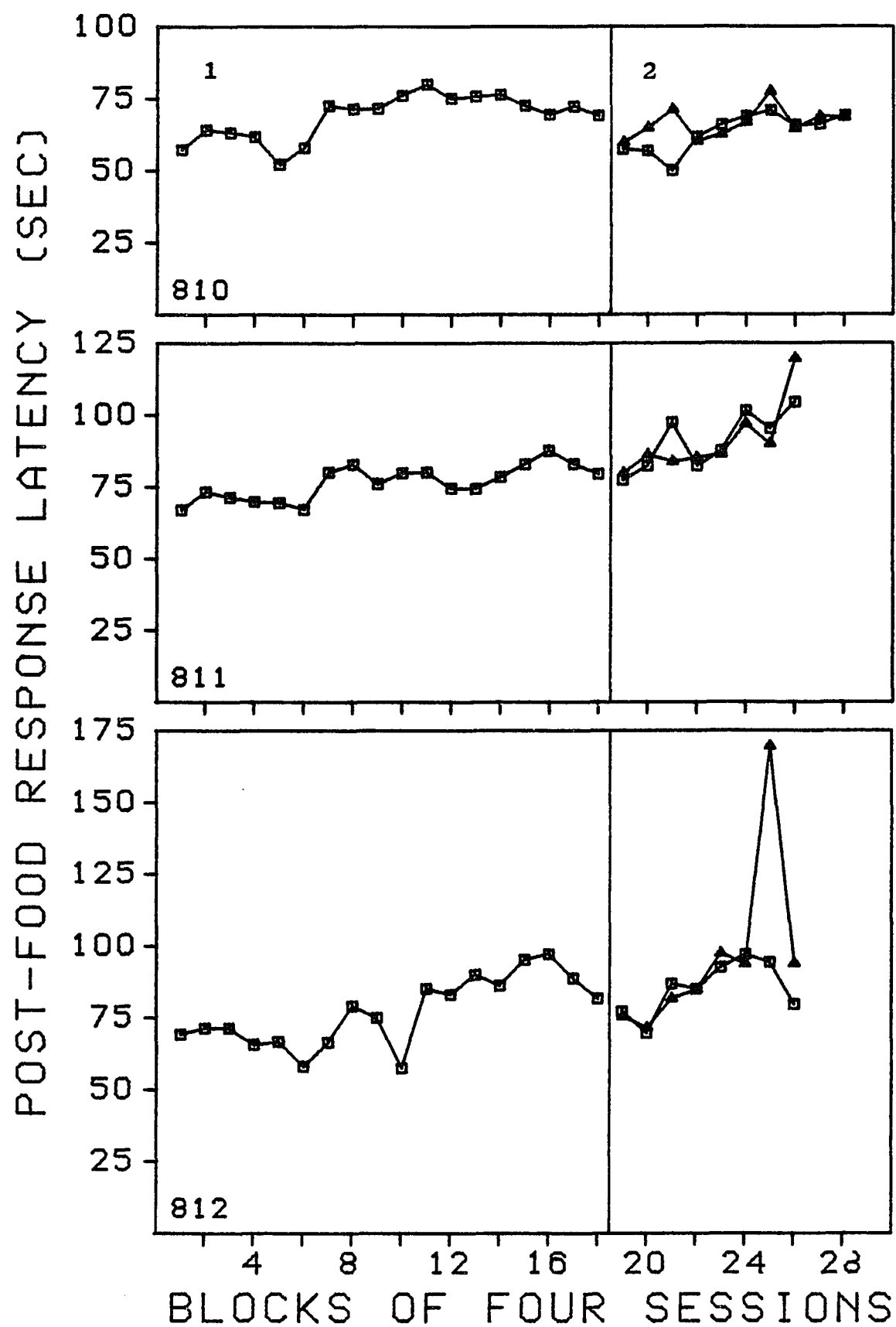
During post-stimulus components, there were no consistent between-subjects differences between pre-food (FS) and pre-stimulus (SS) latencies (Figures 62 and 63). Among control animals during Phase 2 (Figure 64), pre-stimulus latencies were generally slightly longer than were pre-food latencies.

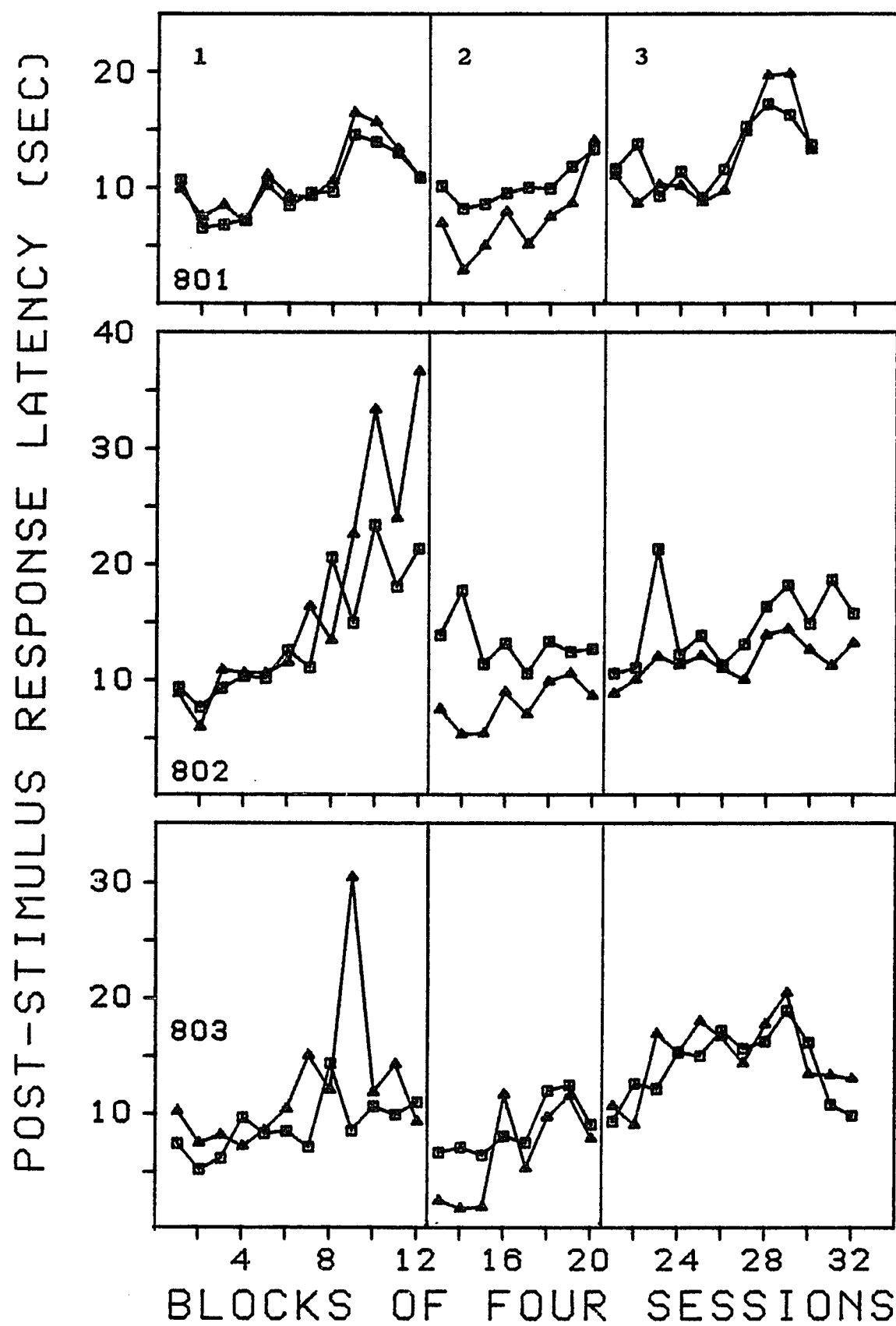
Post-stimulus latencies among control animals generally resembled those among experimental animals. Average post-stimulus latencies were shorter than were average post-food latencies for all subjects.

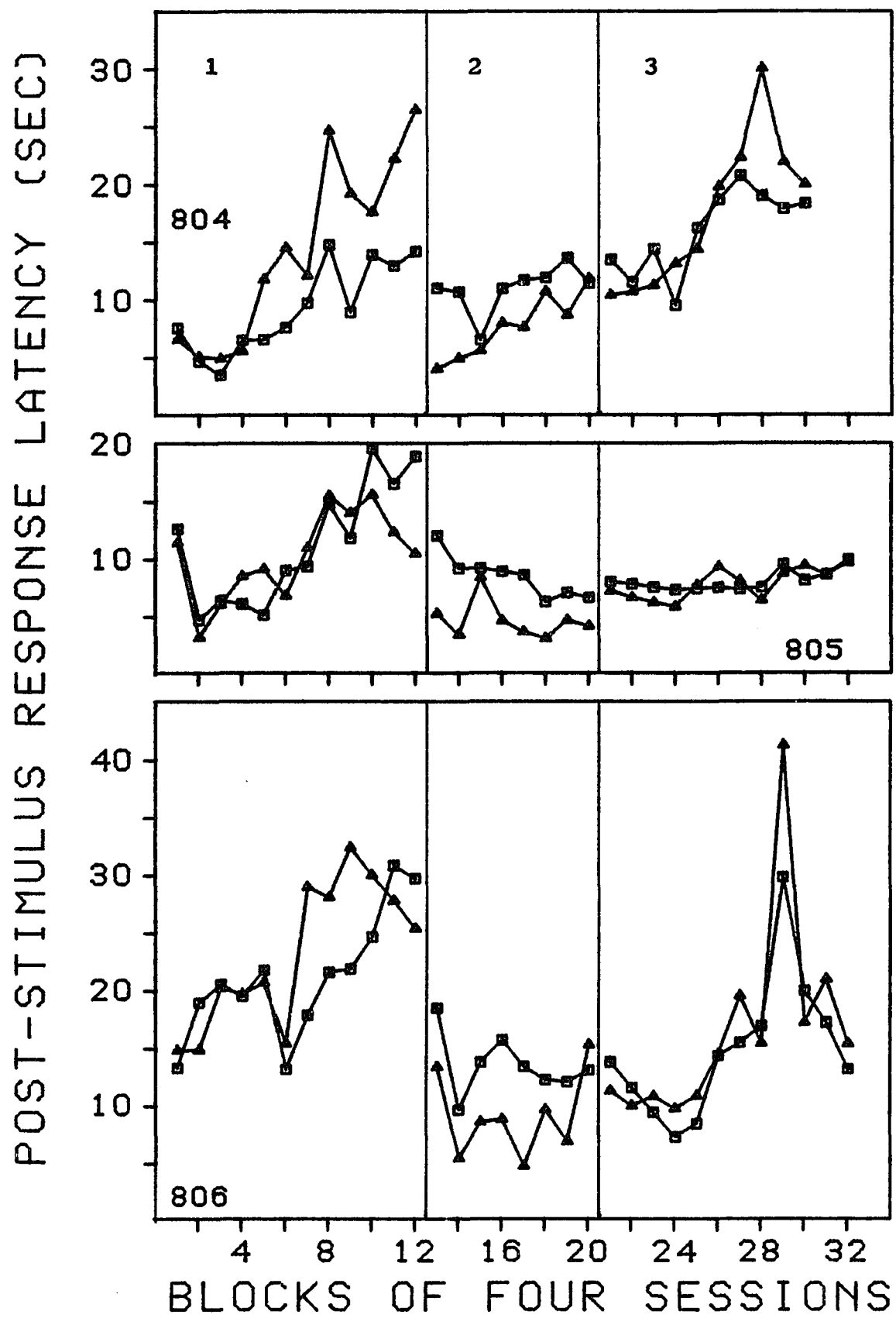


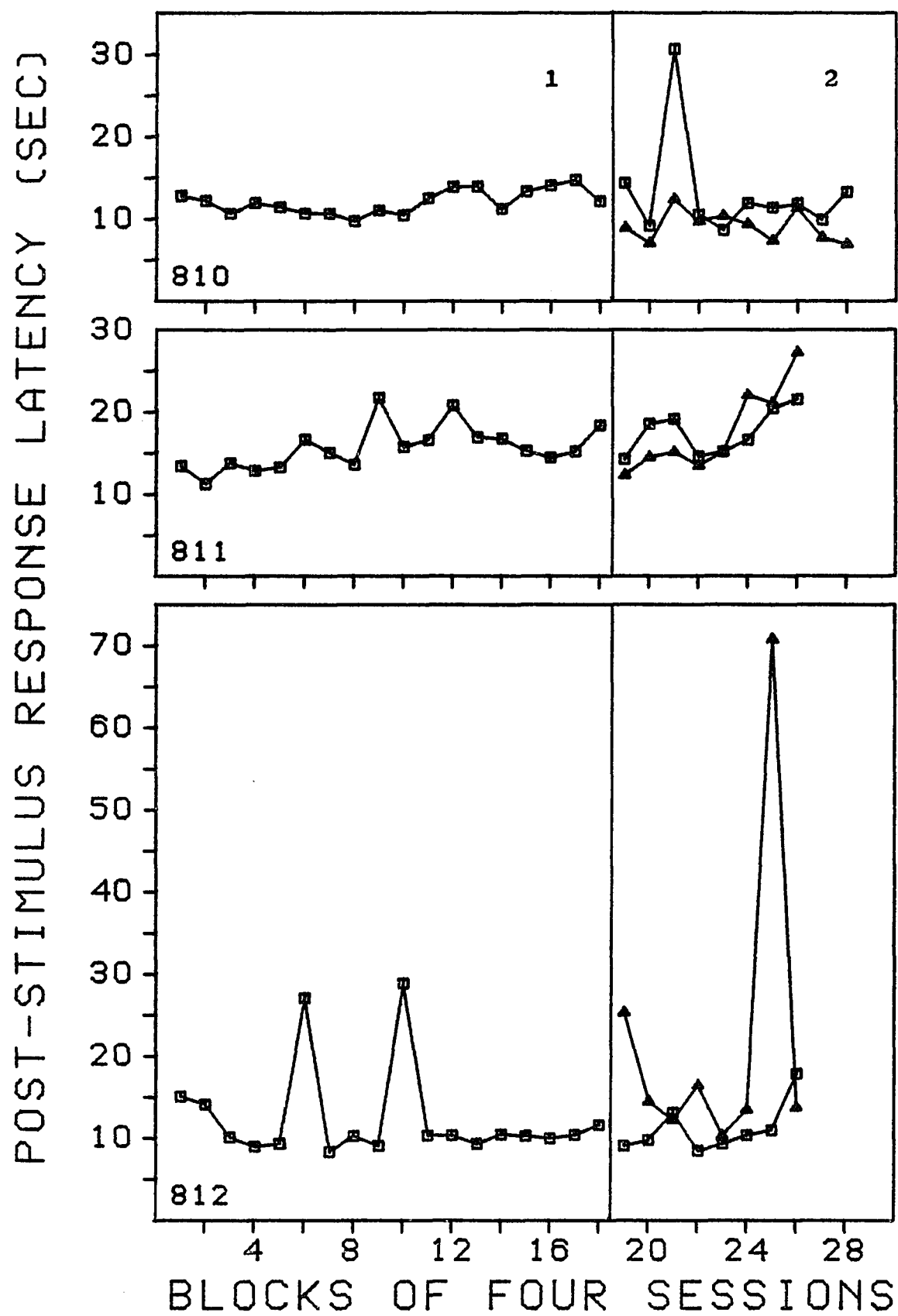










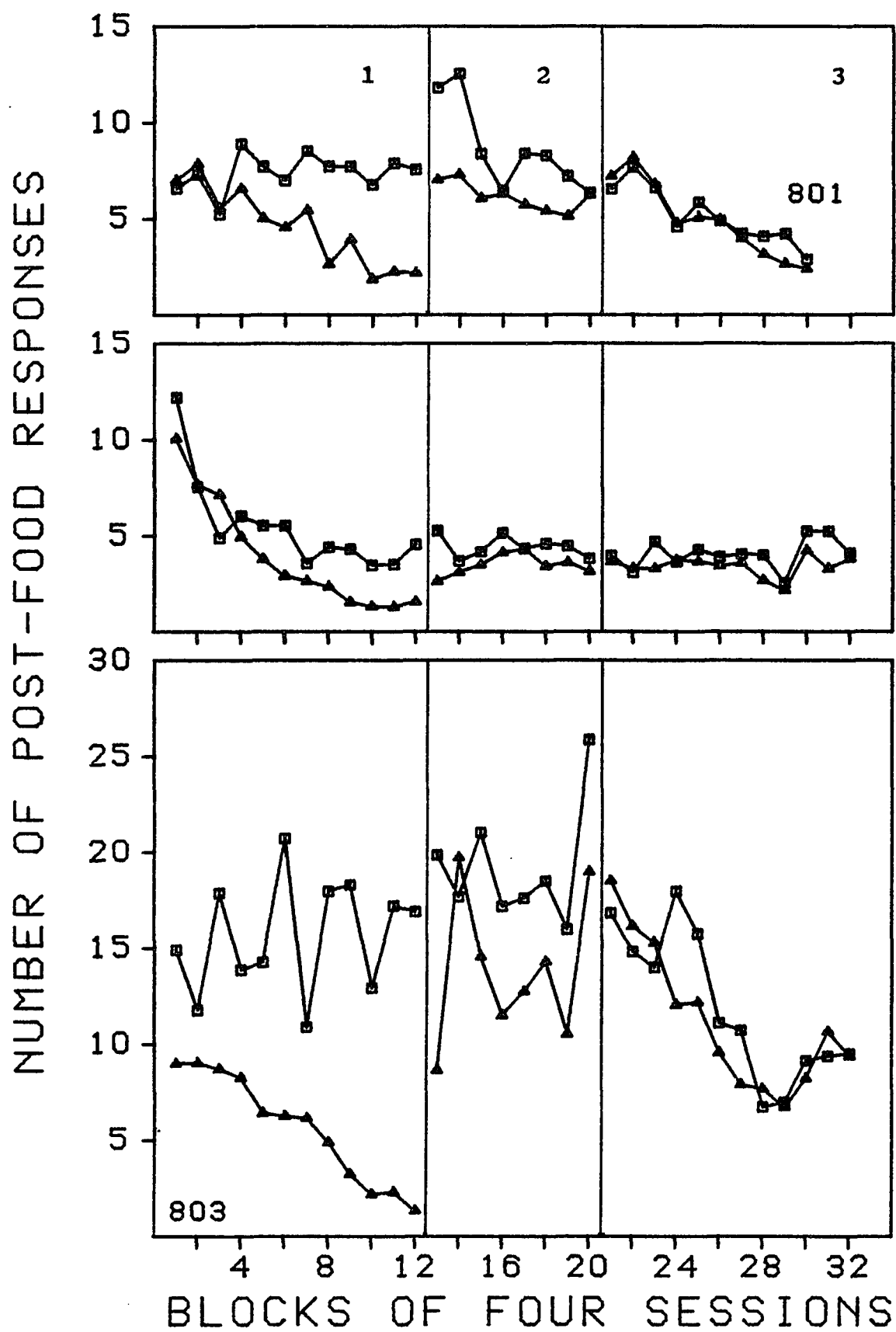


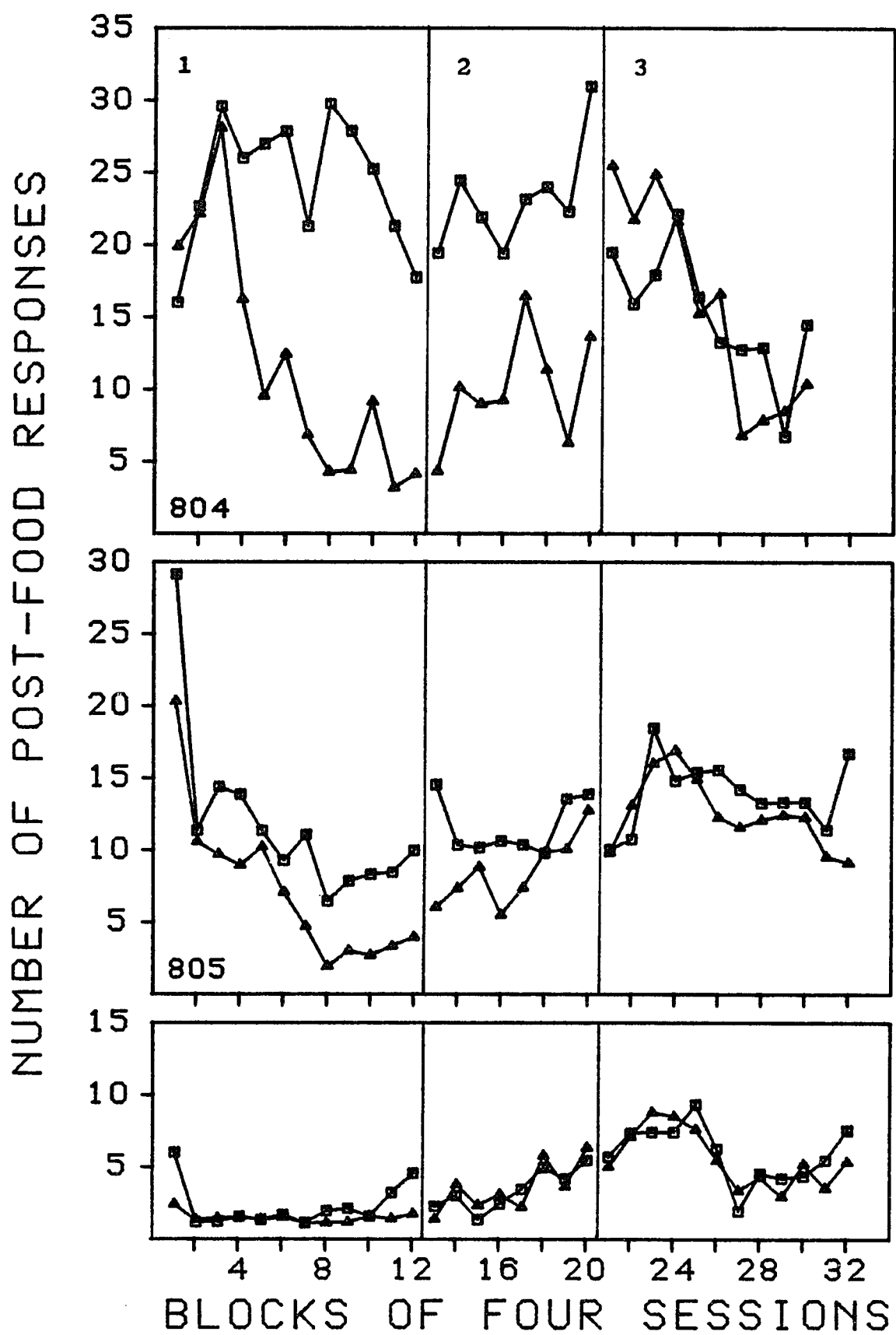
### Lever-Press Counts

Figures 65 - 70. Data represent the mean number of lever-presses per component, for all subjects for which lever-pressing was required, during both post-food (Figures 65 - 67) and post-stimulus (Figures 68 - 70) components. Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. For experimental animals (801 - 806) during Phases 1 and 3, and for control animals (811 and 812) during Phase 2, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations, while triangles represent behavior in the presence of the signal previously correlated with stimulus presentations. Signals were not presented to control animals during Phase 1. Squares represent average post-food behavior for control animals in Figure 61, and average post-stimulus behavior in Figure 64 during Phase 1 for those animals. For Subject 810, squares during Phase 2 represent behavior in the presence of the tone, while triangles represent behavior in the presence of the repetitive click, neither of which was correlated with component outcomes for that animal. Individual data points represent performance averaged over 4 consecutive sessions.

Among experimental subjects (801 - 806), both post-food (Figures 65 and 66) and post-stimulus (Figures 68 and 69) lever-press counts were consistently higher during pre-food (FF, FS) than during pre-stimulus (SF, SS) components at the conclusion of Phase 1. The difference was typically diminished during the course of Phase 2, and seemed to be more reliably recovered during Phase 3 for post-stimulus than for post-food lever-pressing. Among control subjects (811 and 812) during Phase 2, a pre-food/pre-stimulus difference in lever-press counts was similarly more strongly evidenced during post-stimulus than during post-food components.

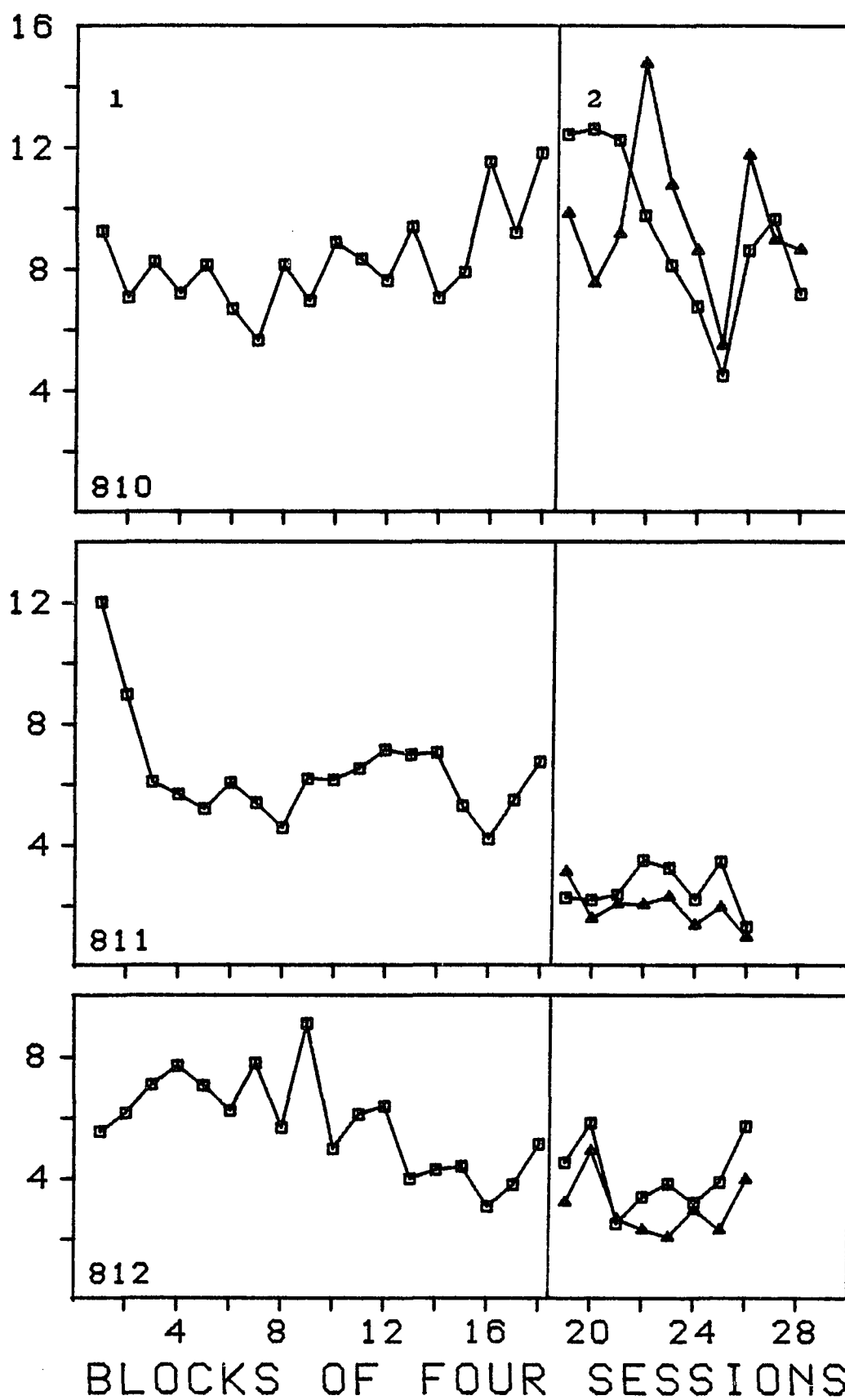
The number of lever-presses per post-stimulus component (Figures 68 - 70) was consistently higher than that for post-food components (Figures 65 - 67). The absolute difference between pre-food and pre-stimulus lever-press counts was greater for post-stimulus than for post-food components (19.5 vs. 7.7).

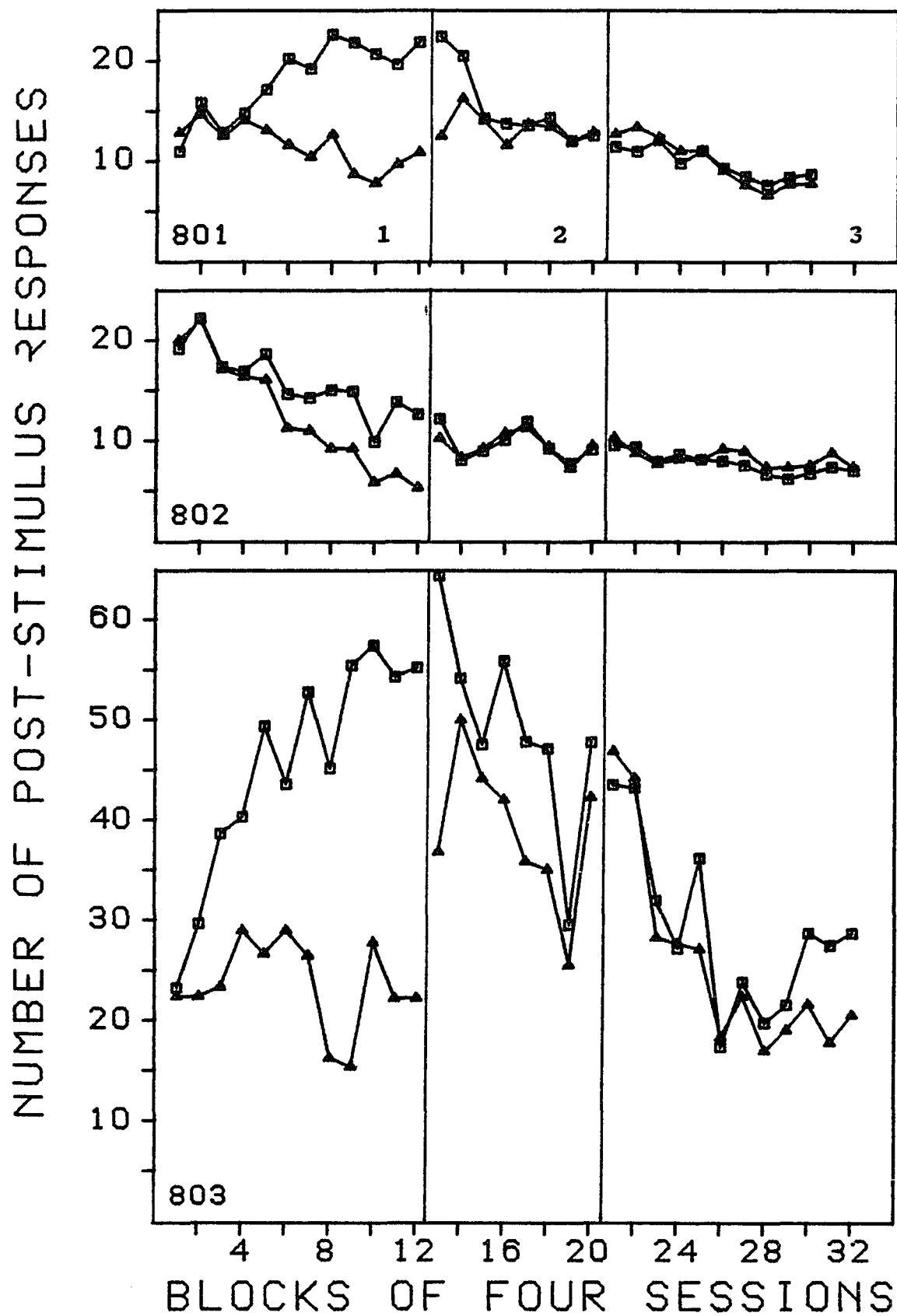


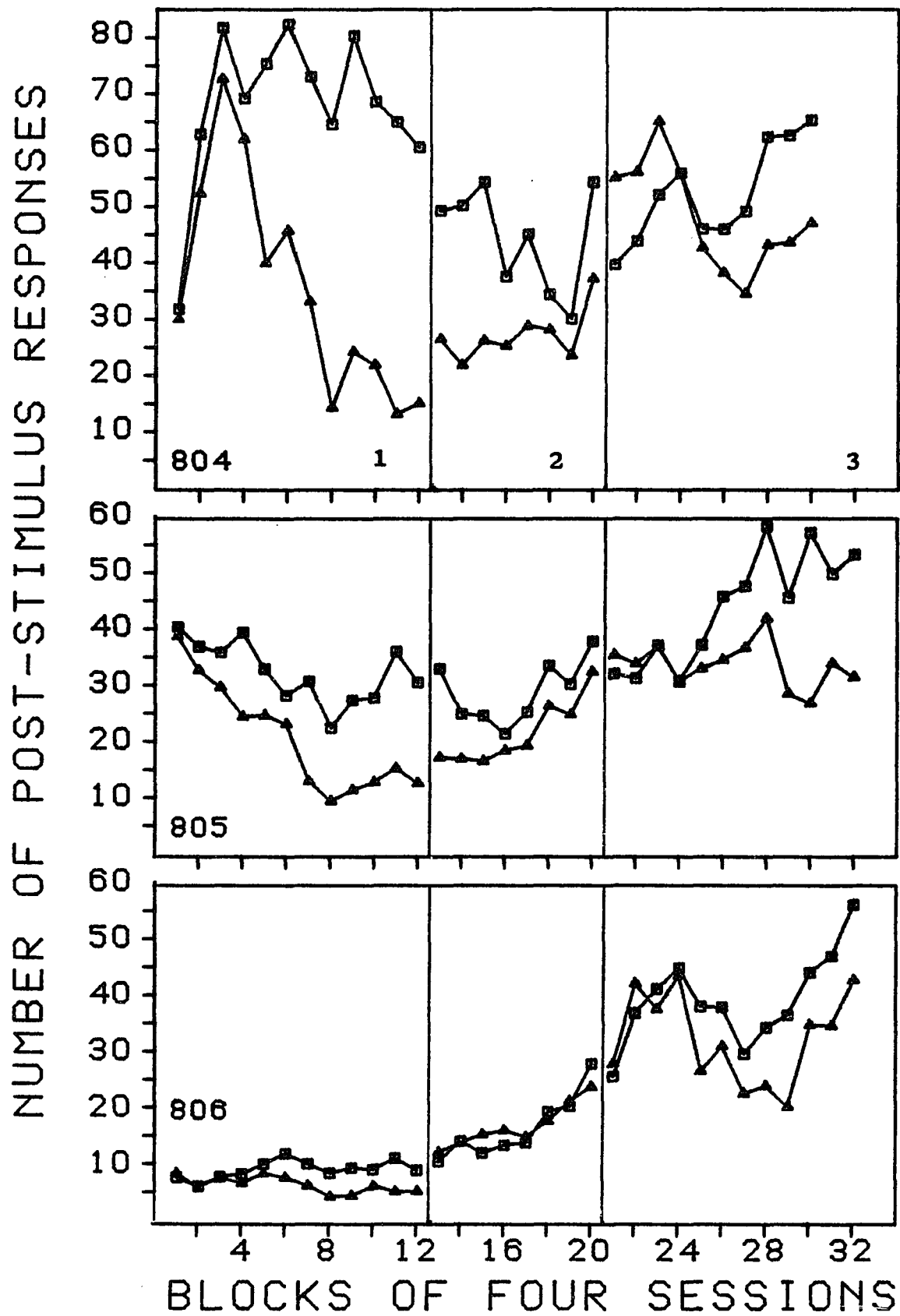


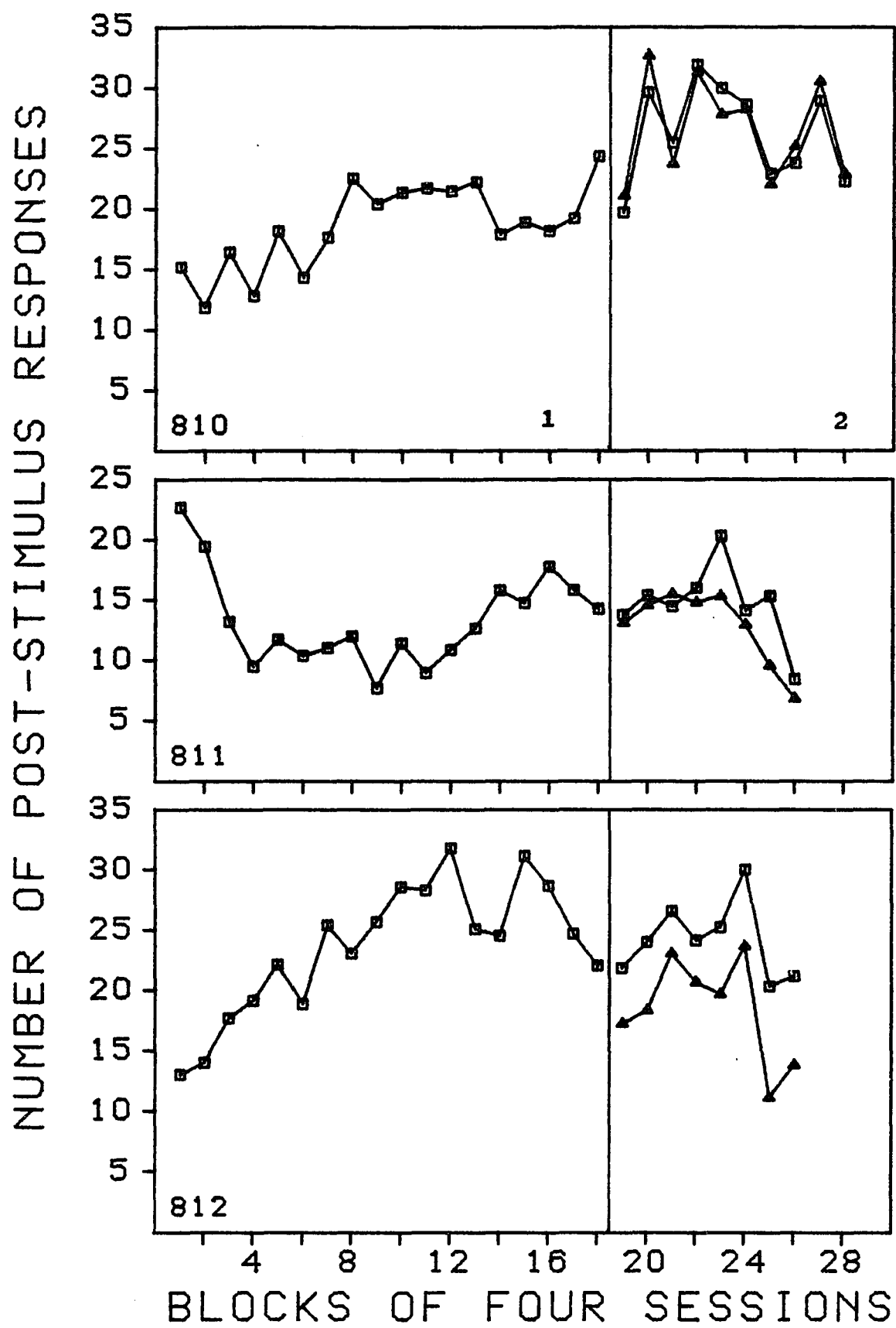


NUMBER OF POST-FOOD RESPONSES







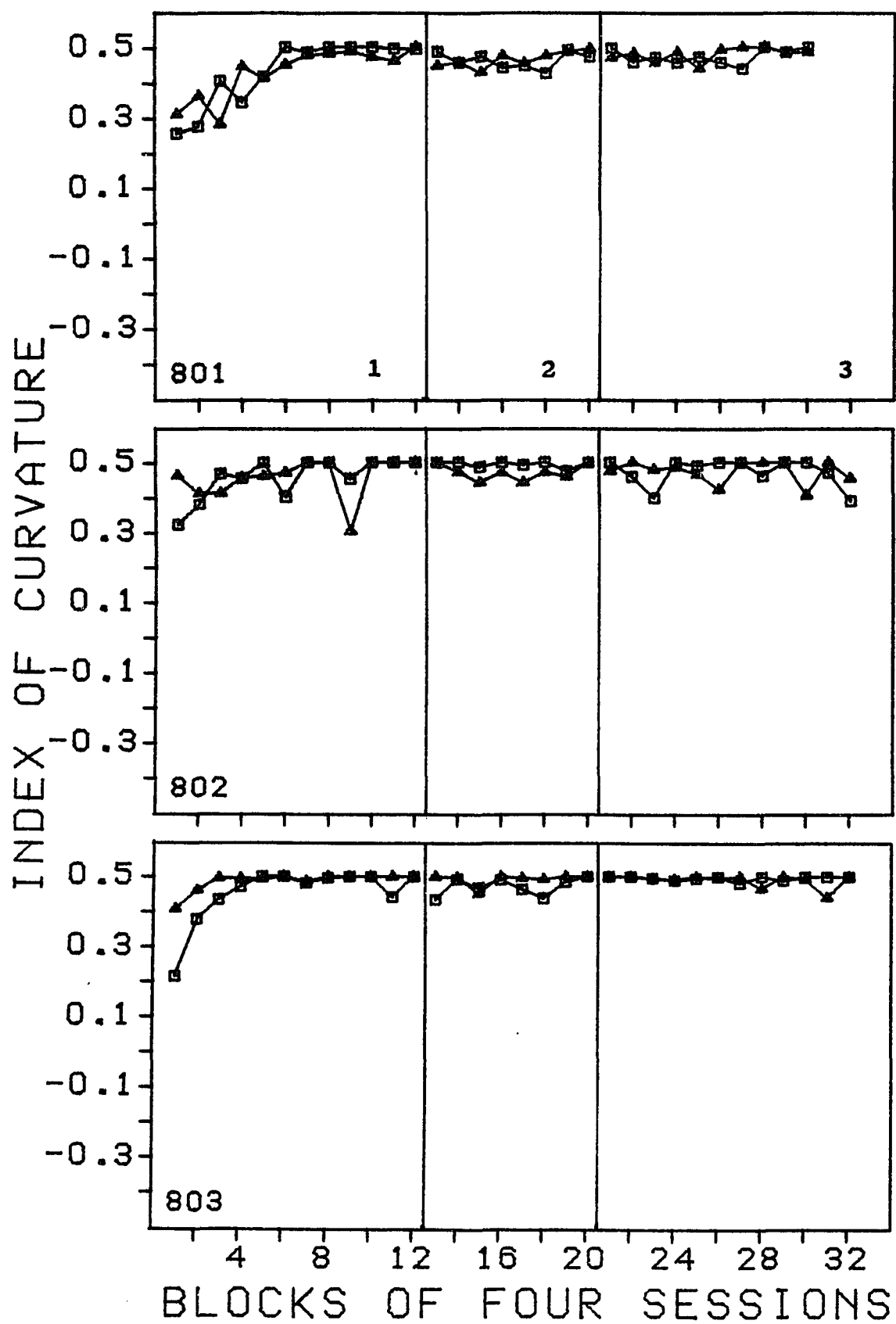


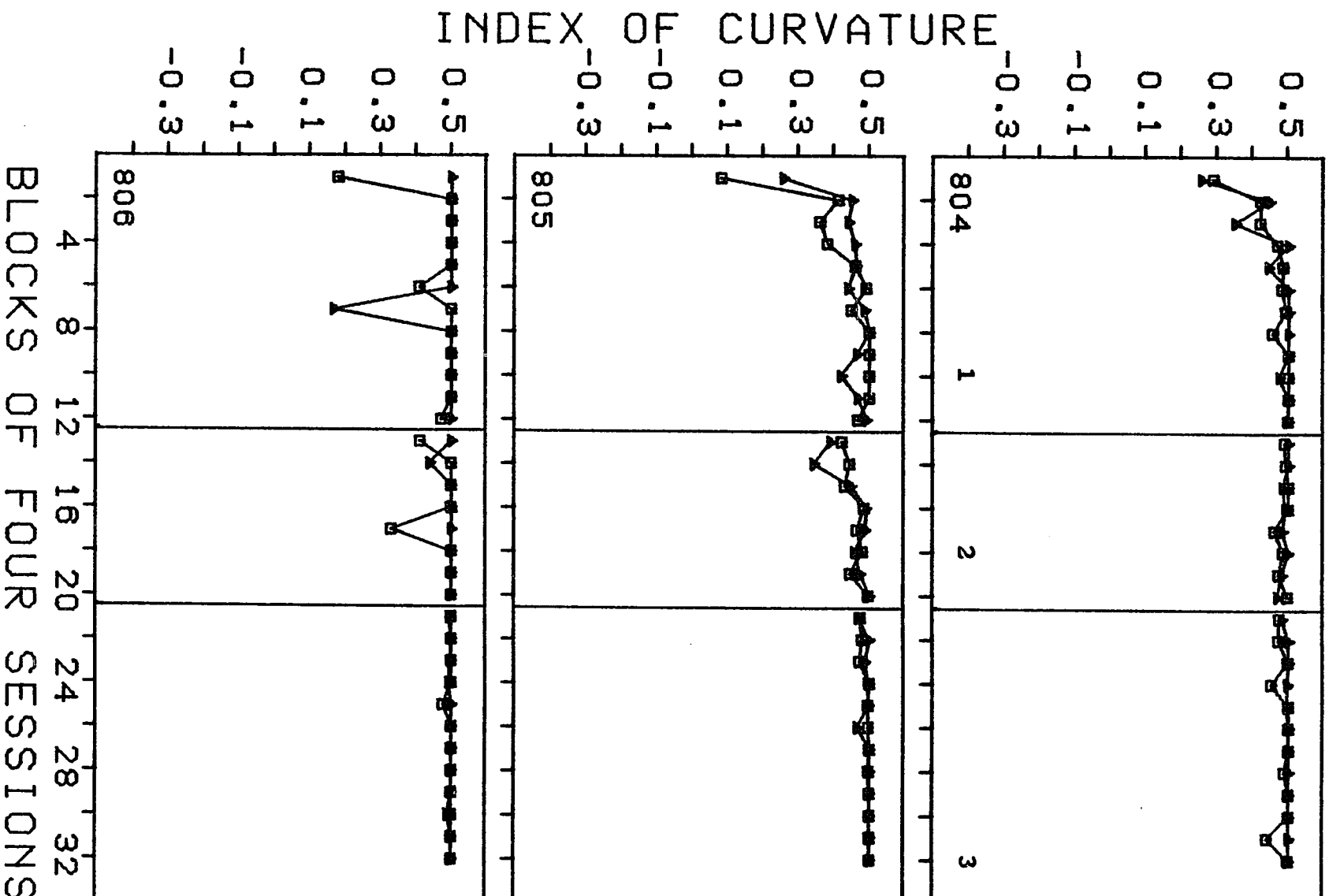
### Indices of Curvature:

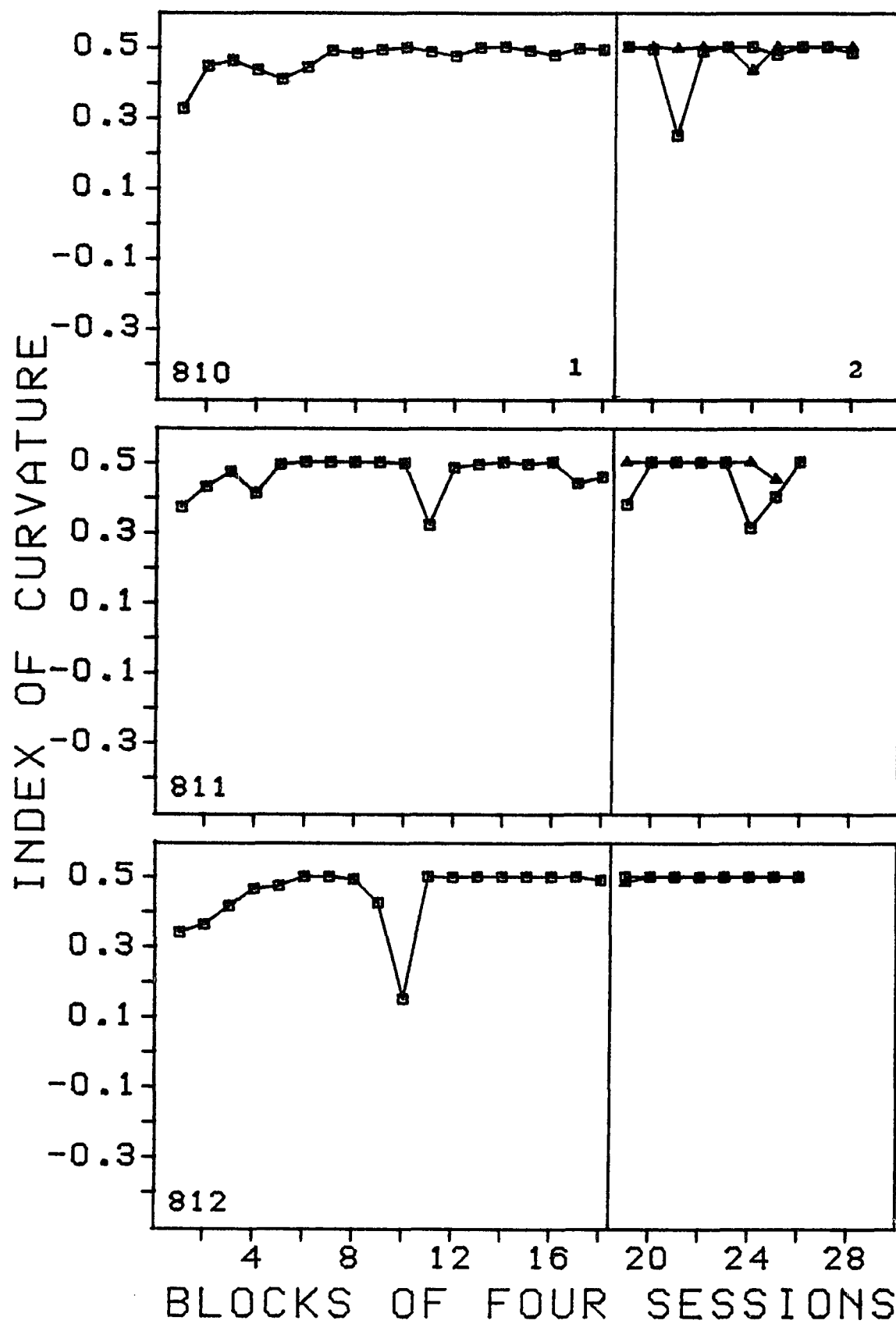
#### Post-Food Lever-Pressing

Figures 71 - 73. Data represent indices of curvature, as described under Method for post-food lever-press distributions of all subjects for which lever-pressing was required (801 - 806, 810 - 812). Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. For experimental animals (801 - 806) during Phases 1 and 3, and for control animals (811 and 812) during Phase 2, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations, while triangles represent behavior in the presence of the signal previously correlated with stimulus presentations. Signals were not presented to control animals during Phase 1. Squares represent average post-food behavior for control animals in Figure 61, and average post-stimulus behavior in Figure 64 during Phase 1 for those animals. For Subject 810, squares during Phase 2 represent behavior in the presence of the tone, while triangles represent behavior in the presence of the repetitive click, neither of which was correlated with component outcomes for that animal. Individual data points represent performance averaged over 4 consecutive sessions.

After the first few sessions of training, the IC remained close to the maximum possible positive value (0.5) for all subjects, indicating that most lever-presses occurred late during post-food components. Average IC's were similar for control and experimental animals, and were not affected by changes in experimental conditions. Pre-food (FF) and pre-stimulus (SF) indices did not differ.







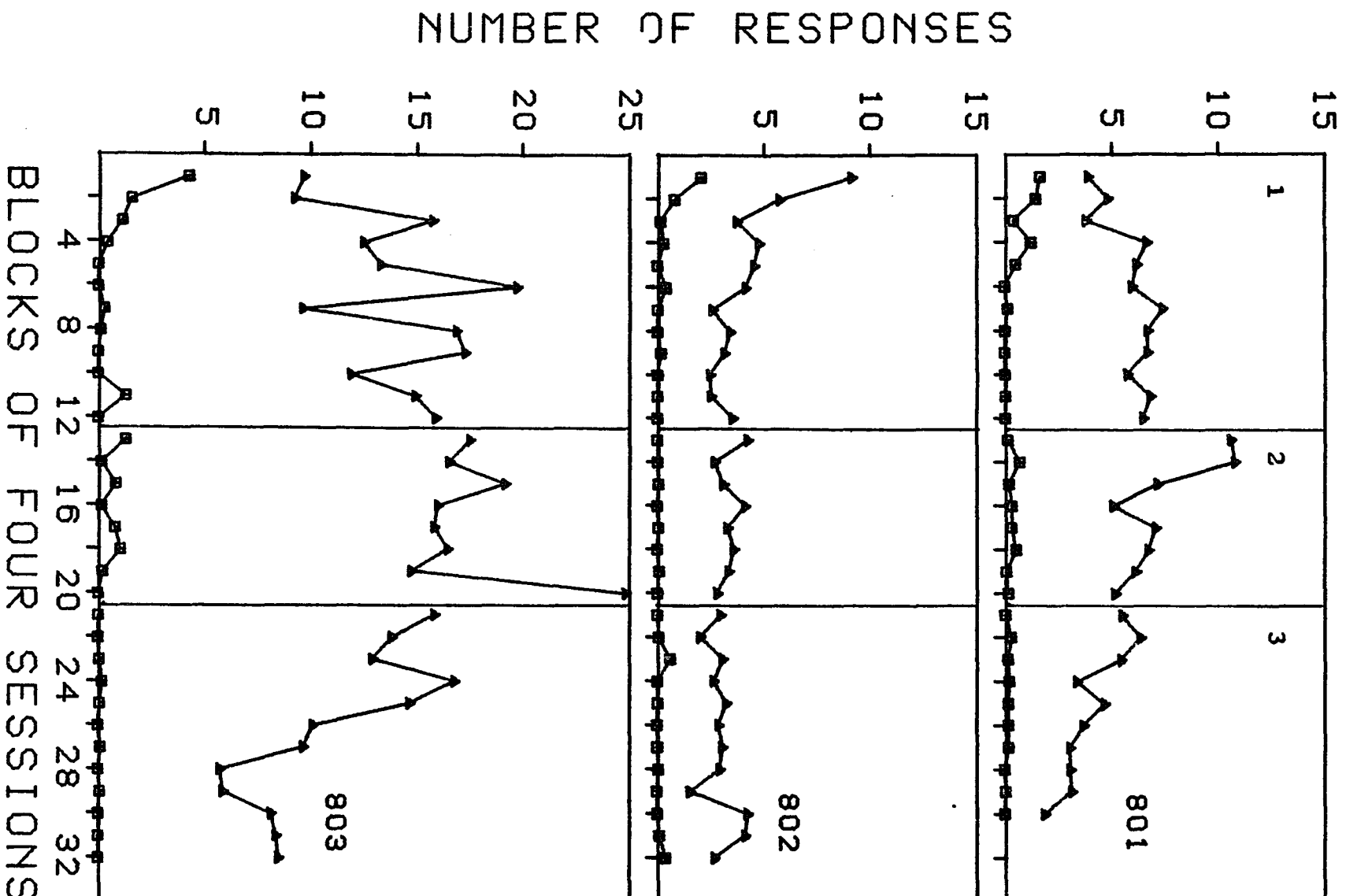


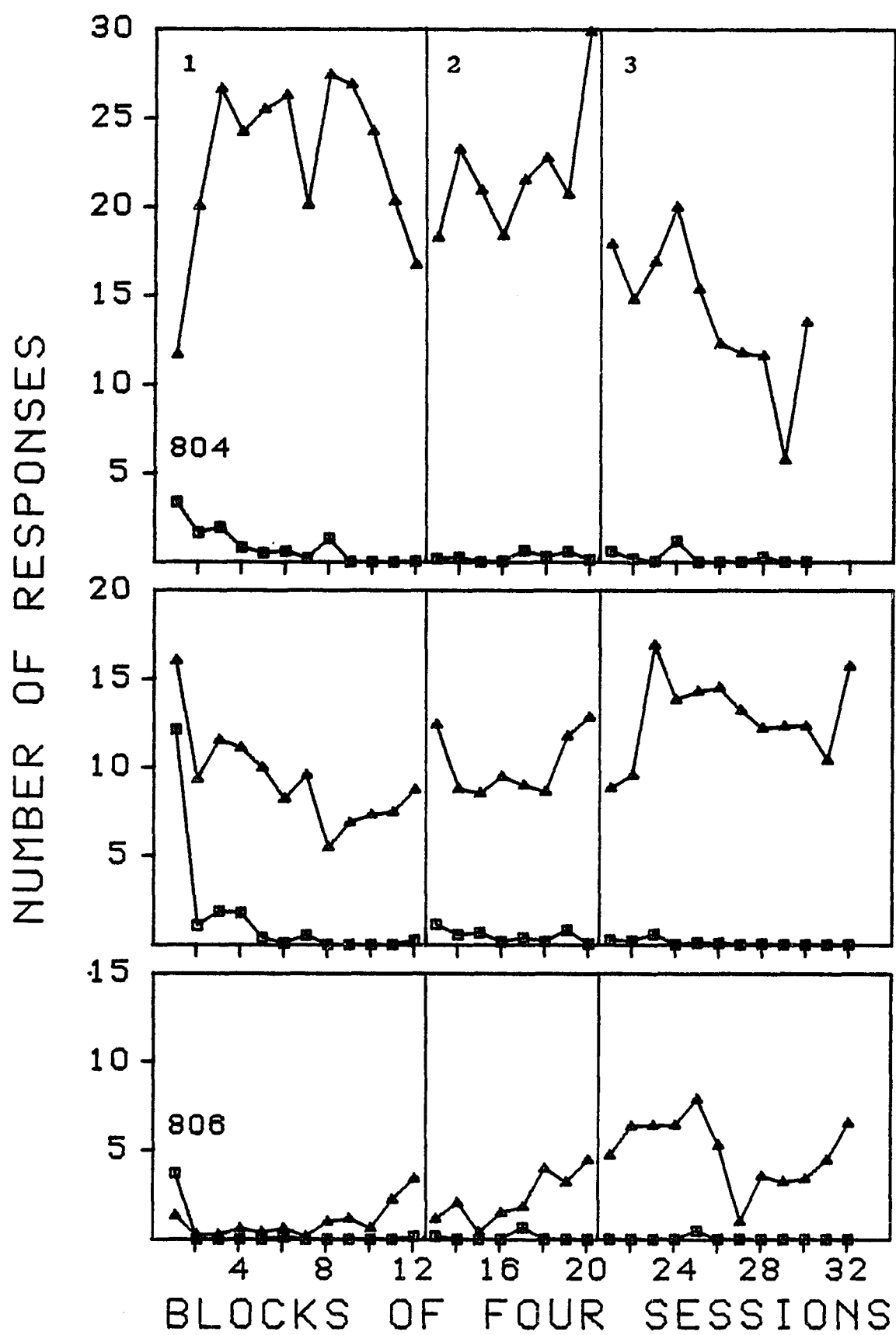
### Lever-Press Distributions

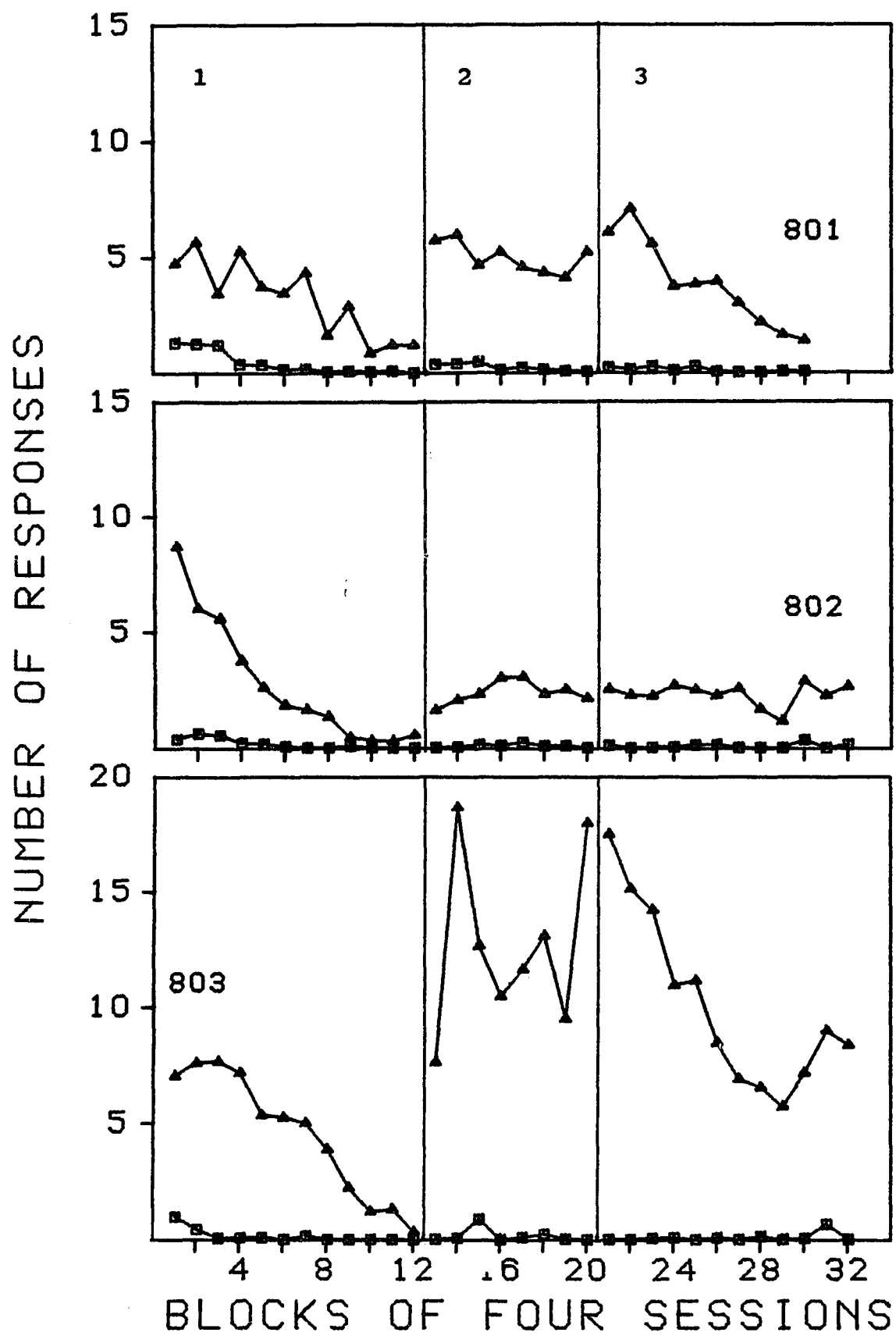
Figures 74 - 81. Data represent the mean number of lever-presses per component, broken down according to whether they occurred during the first or the second half of components for all subjects in the response-dependent experimental condition (801 - 806). FF distributions are presented in Figures 74 and 75; SF distributions, in Figures 76 and 77; FS distributions, in Figures 78 and 79; and SS distributions, in Figures 80 and 81. Experimental phases, separated by vertical lines, are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. Within each figure, squares represent behavior during the first half of a component, and triangles represent behavior during the second half of a component. Individual data points represent performance averaged over 4 consecutive sessions.

The post-food distributions (Figures 74 - 77) confirm that most lever-pressing occurred during the second half of post-food components. FF distributions resembled SF distributions,

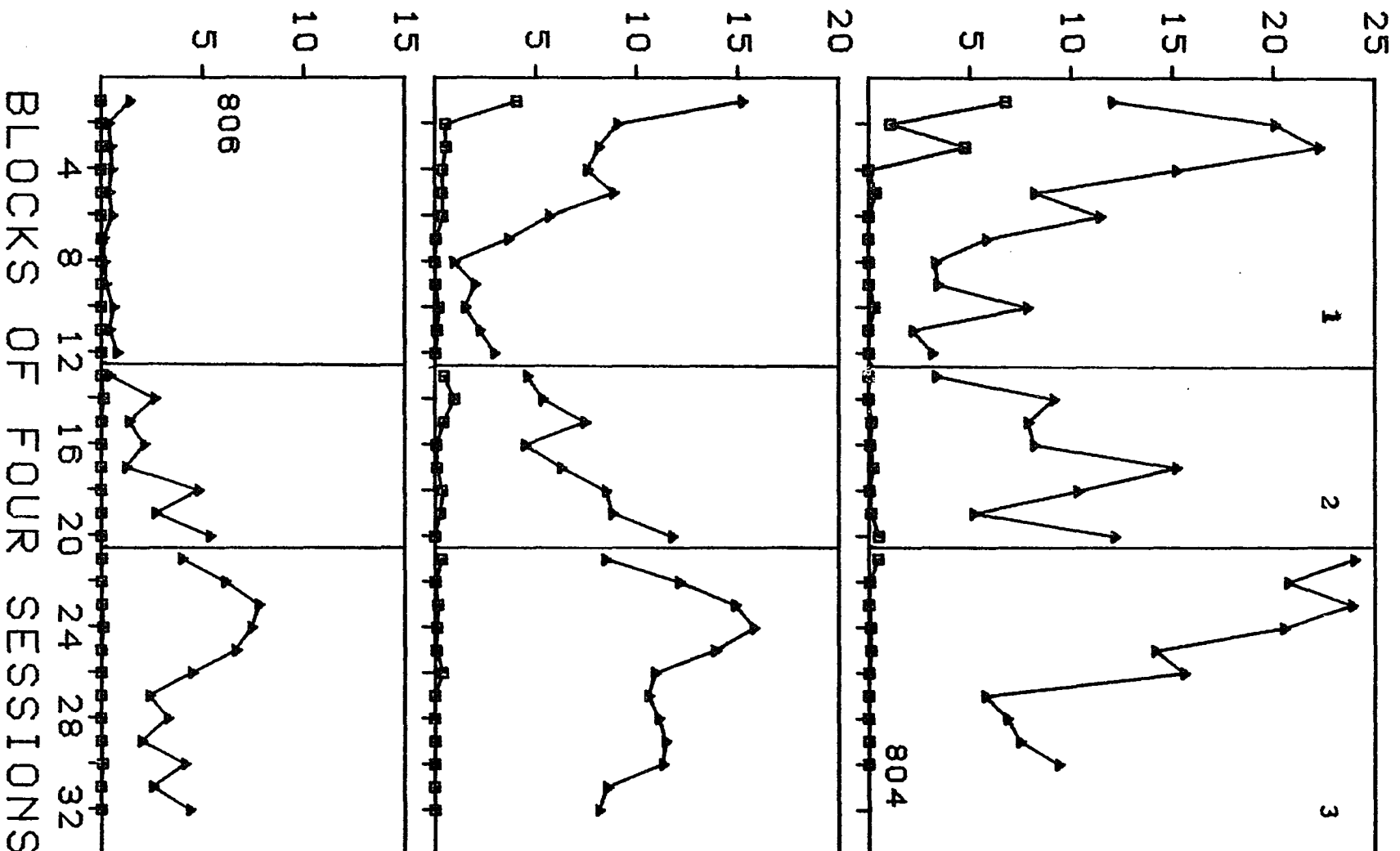
Post-stimulus distributions (Figures 78 - 81), by contrast, exhibit a difference between pre-food (FS) and pre-stimulus (SS) components during Phases 1 and 3. Pre-food distributions (Figures 78 and 79) exhibited a pattern generally similar to the typical post-food pattern-- lever-pressing occurred at a higher rate during the second half than it did during the first half of pre-food components. When the correlation between signals and component outcomes was removed (Phase 2), the FS lever-press pattern of Phase 1 vanished so that lever-pressing occurred at a relatively constant rate during components. The pattern of behavior seen in Phase 2 resembled that seen during SS components (Figures 80 and 81) throughout the experiment. Recovery of the pre-food pattern during Phase 3 is most evident among those subject presented with signal pair S2 (Table 2) during Phase 1 (804 - 806).

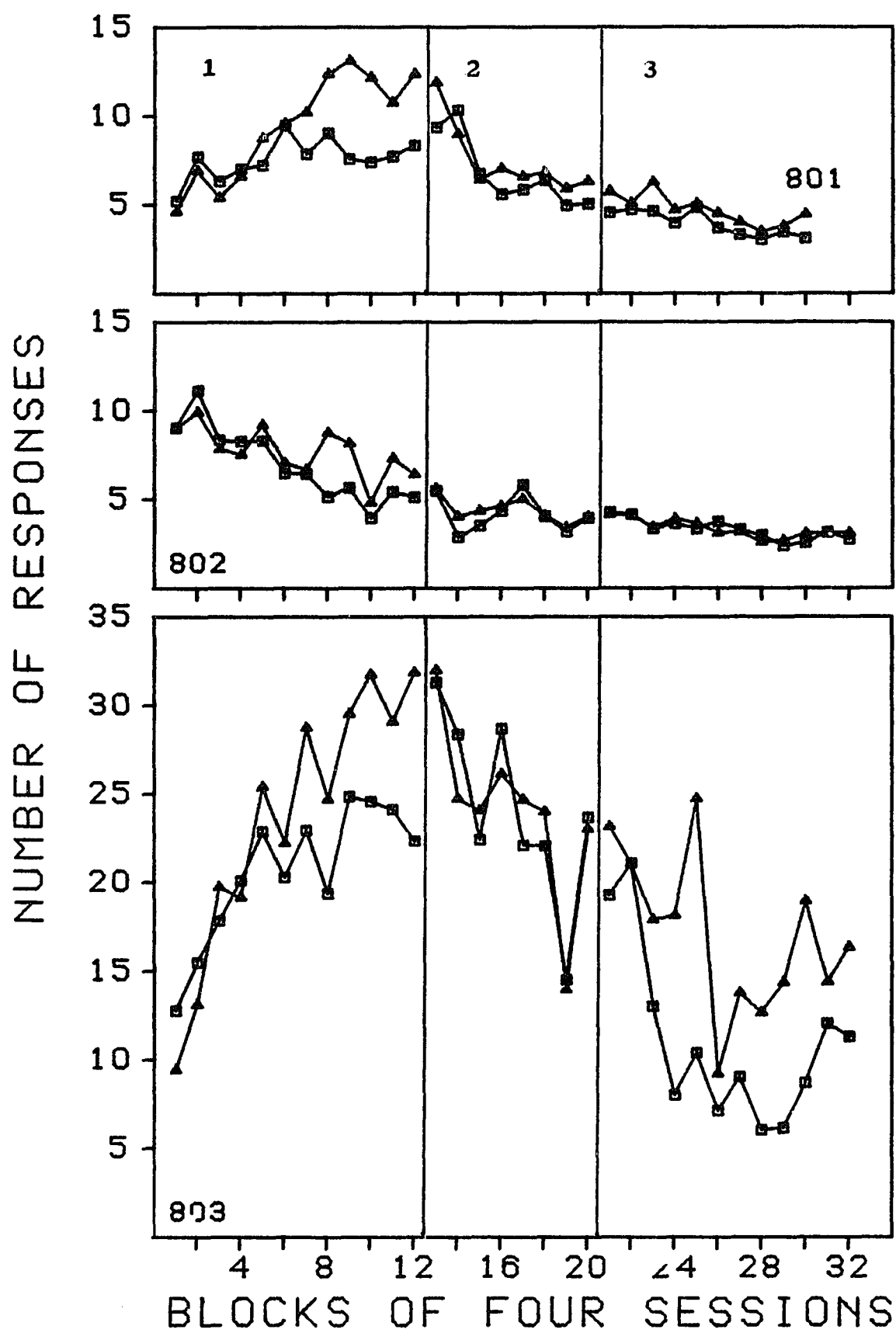


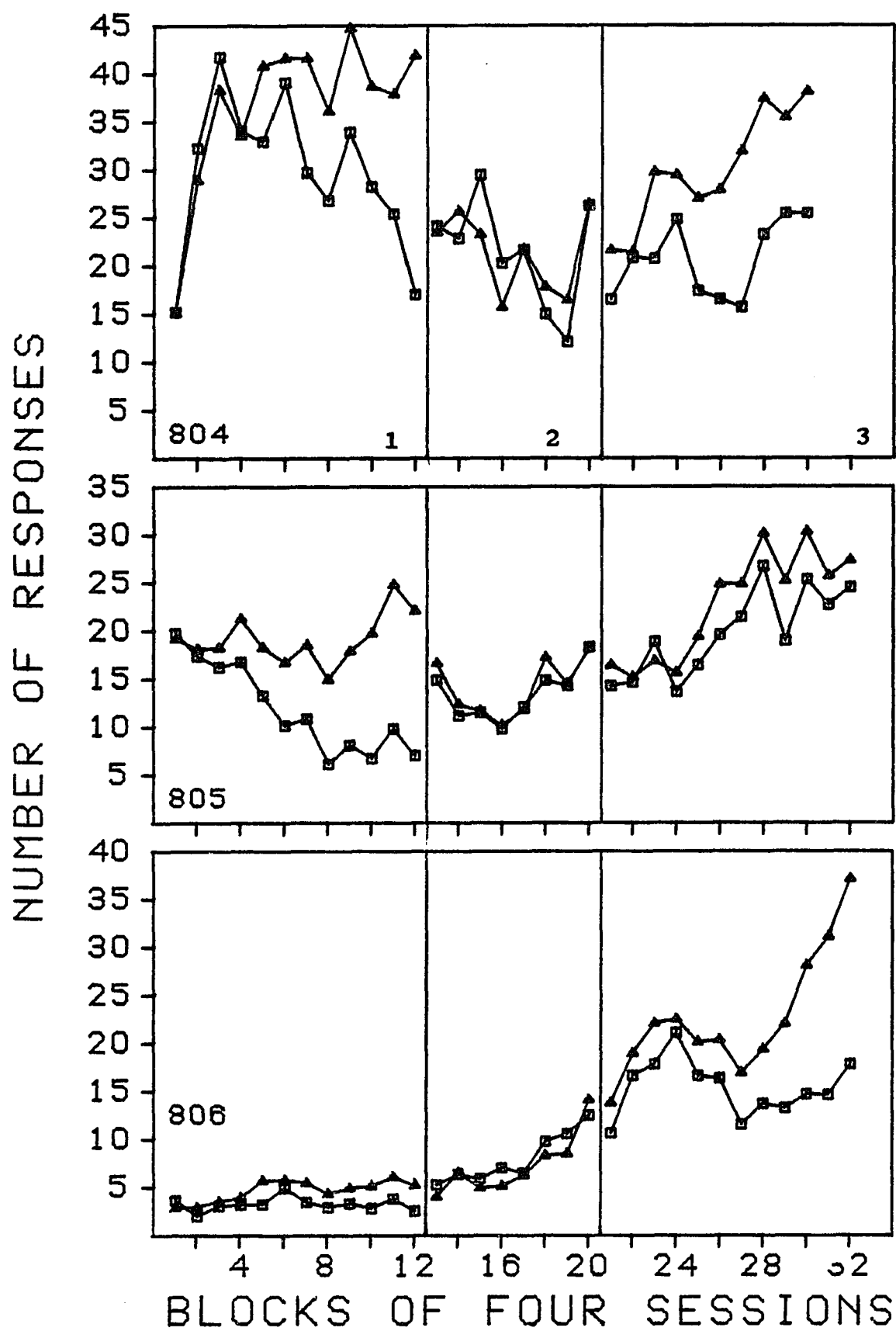


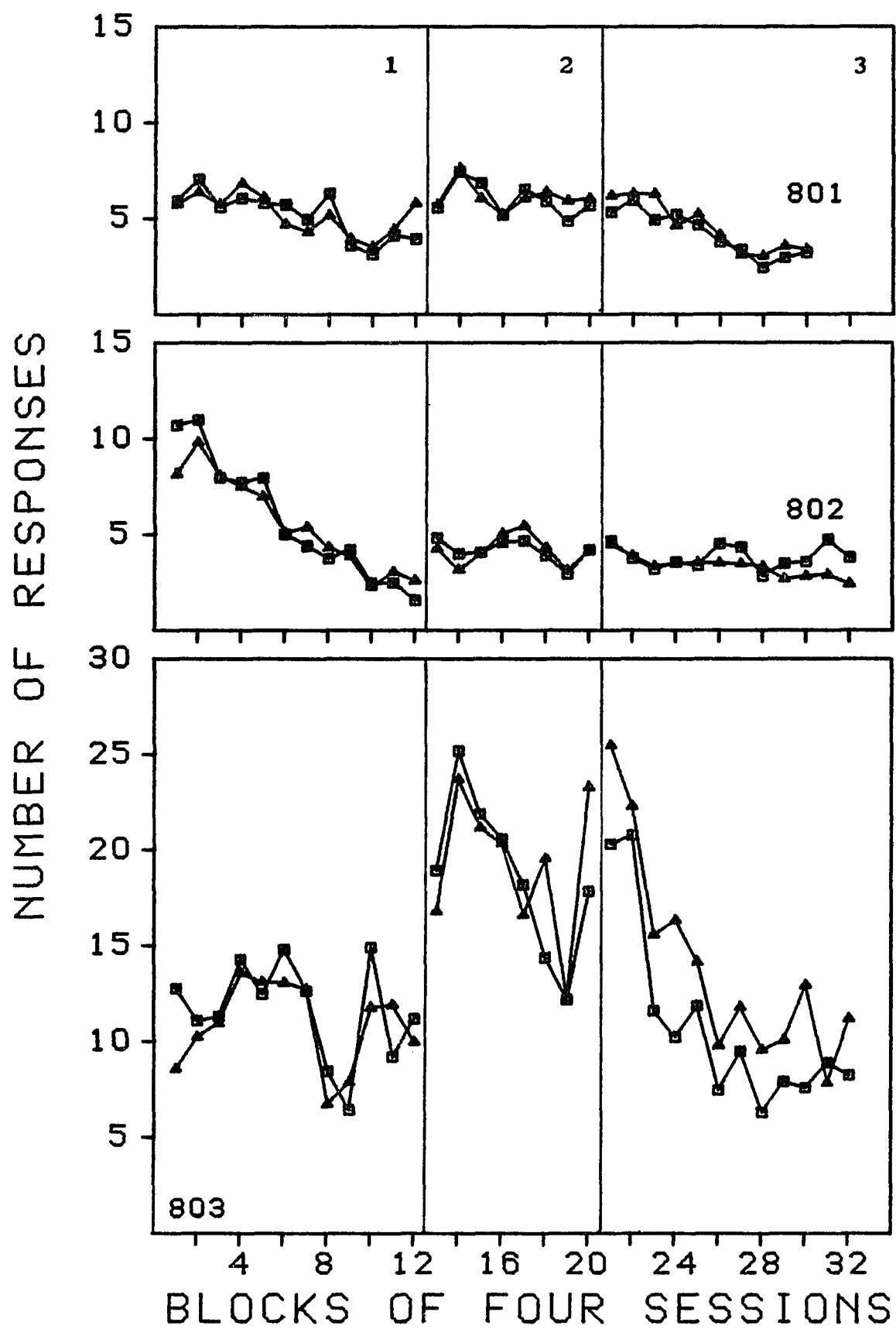


## NUMBER OF RESPONSES

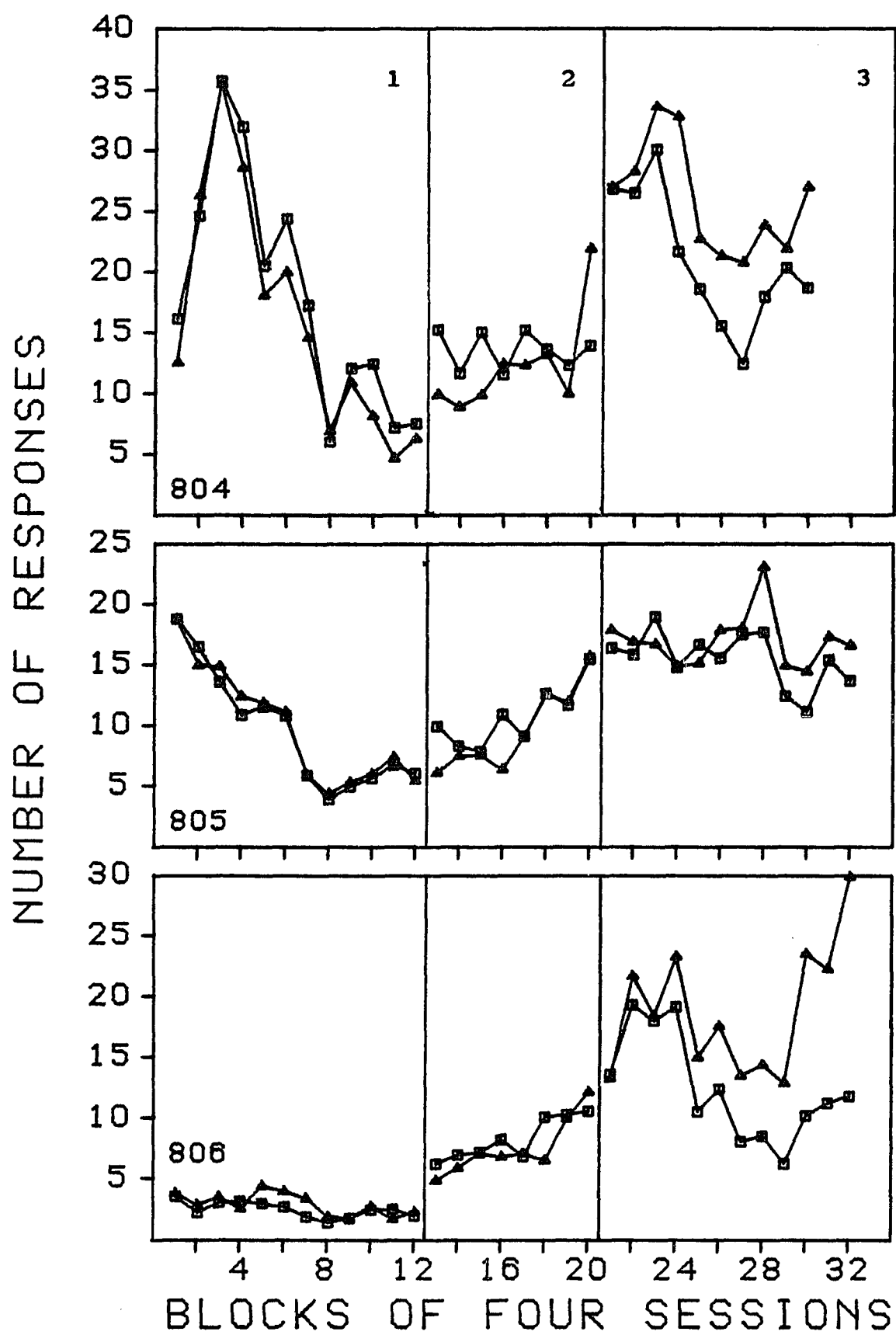








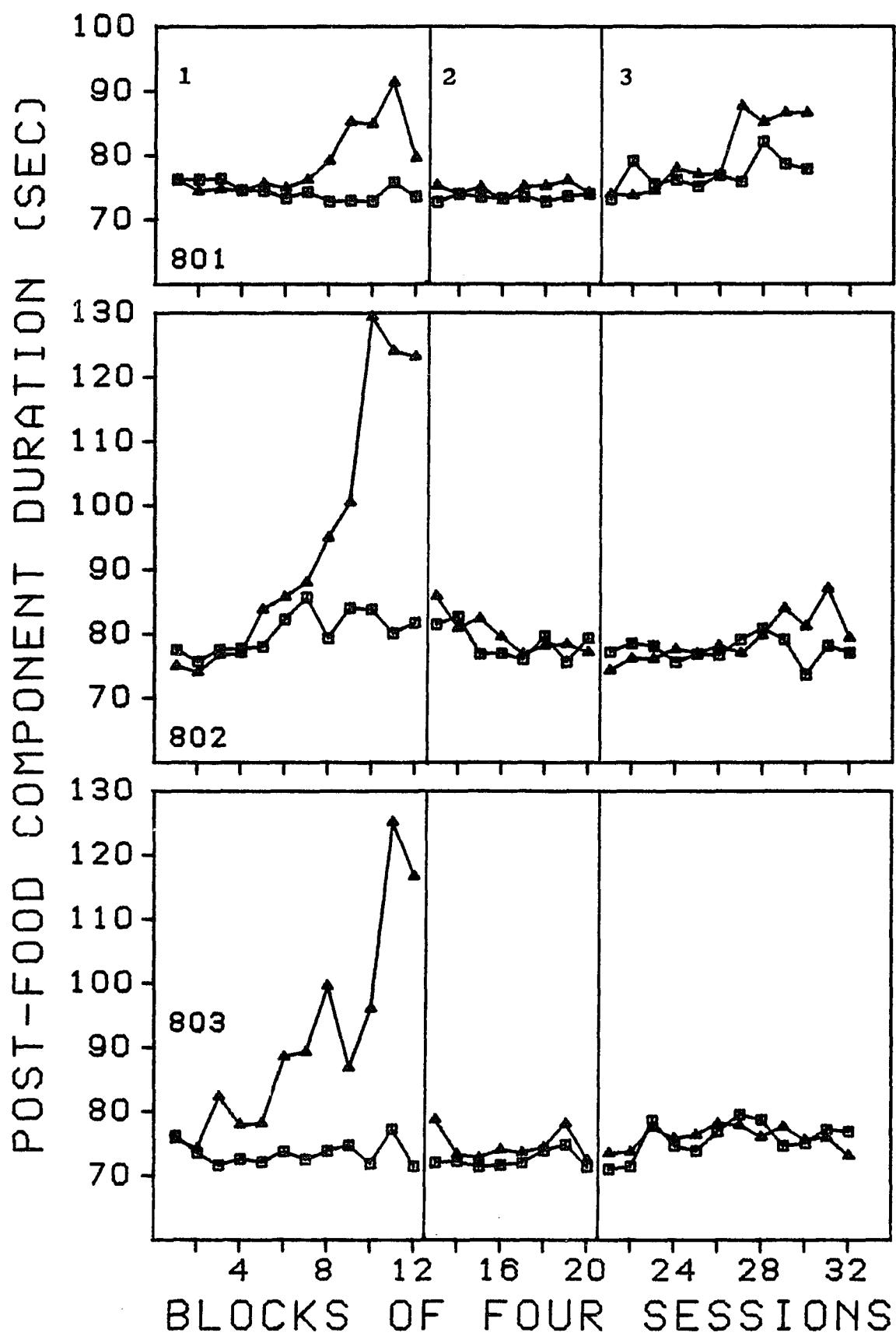


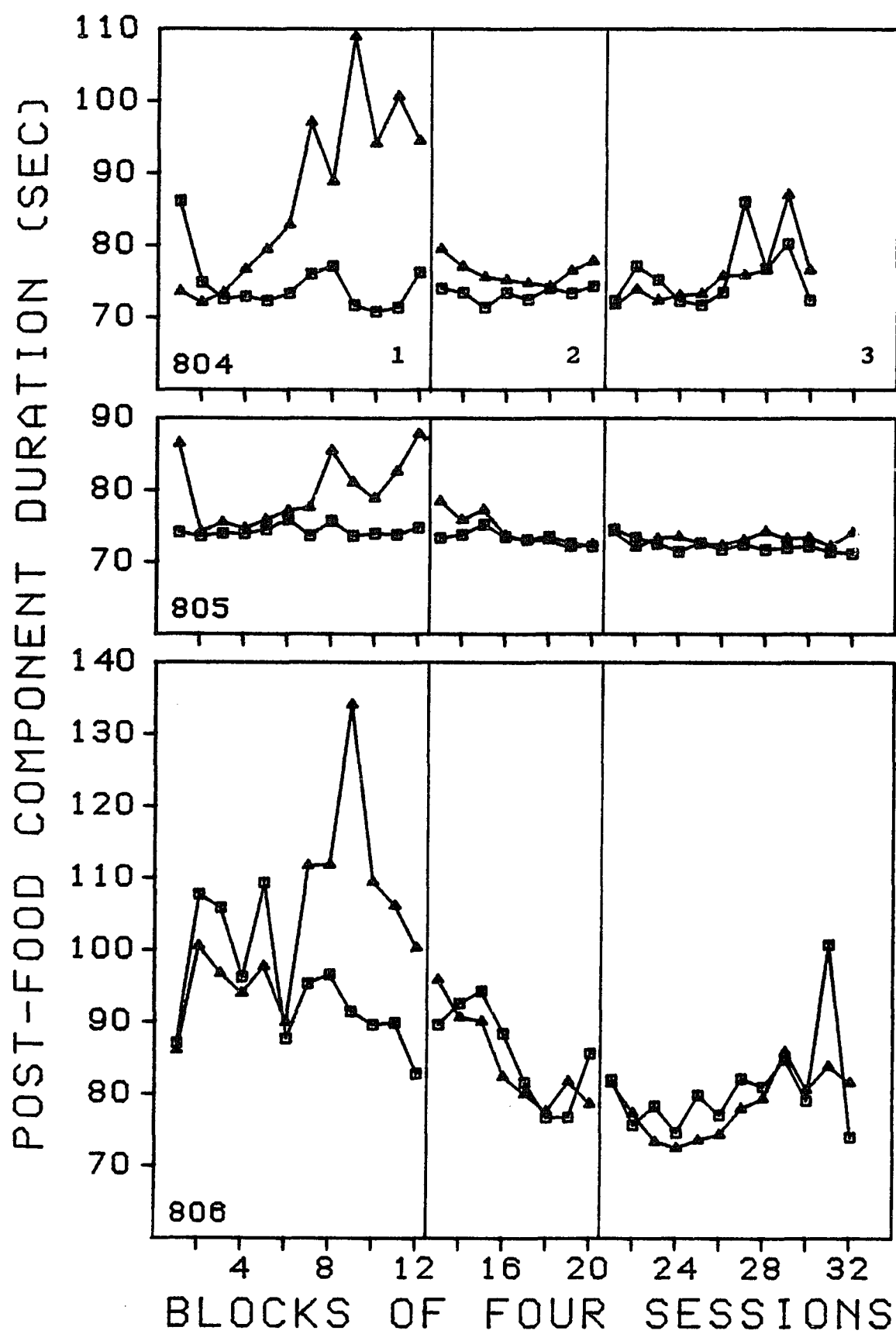


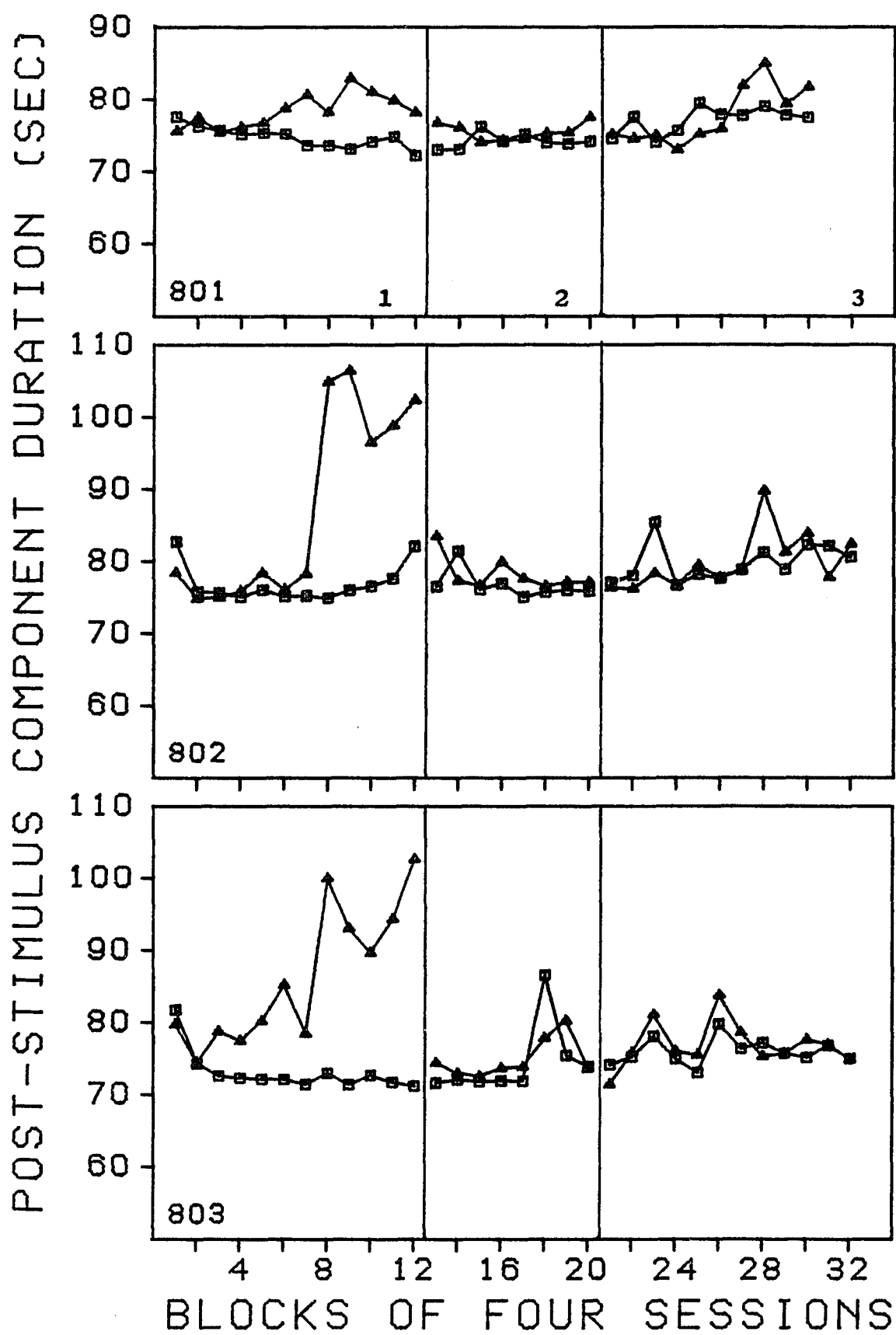
### Component Durations

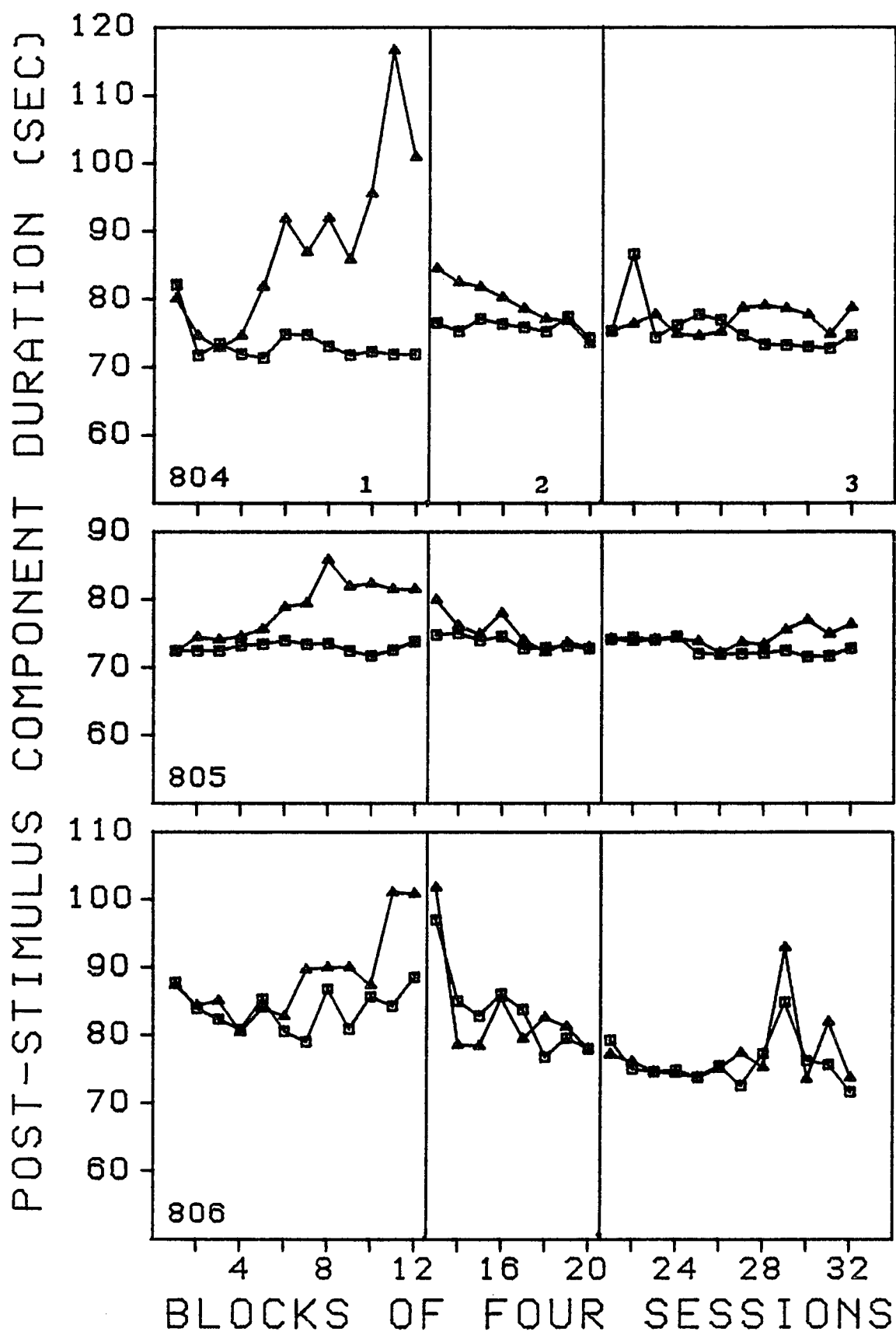
Figures 82 - 85. Data represent the mean durations of post-food (Figures 82 and 83) and post-stimulus (Figures 84 and 85) components for Subjects 801 - 806. Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-food components, while triangles represent pre-stimulus components. During Phase 2, squares represent components in the presence of the signal previously correlated with food presentations, while triangles represent components in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.

Pre-stimulus components were longer in all cases than were pre-food components at the conclusion of Phase 1. The difference disappeared during Phase 2 and was generally not recovered during Phase 3. Mean post-stimulus component durations did not differ from mean post-food component durations.





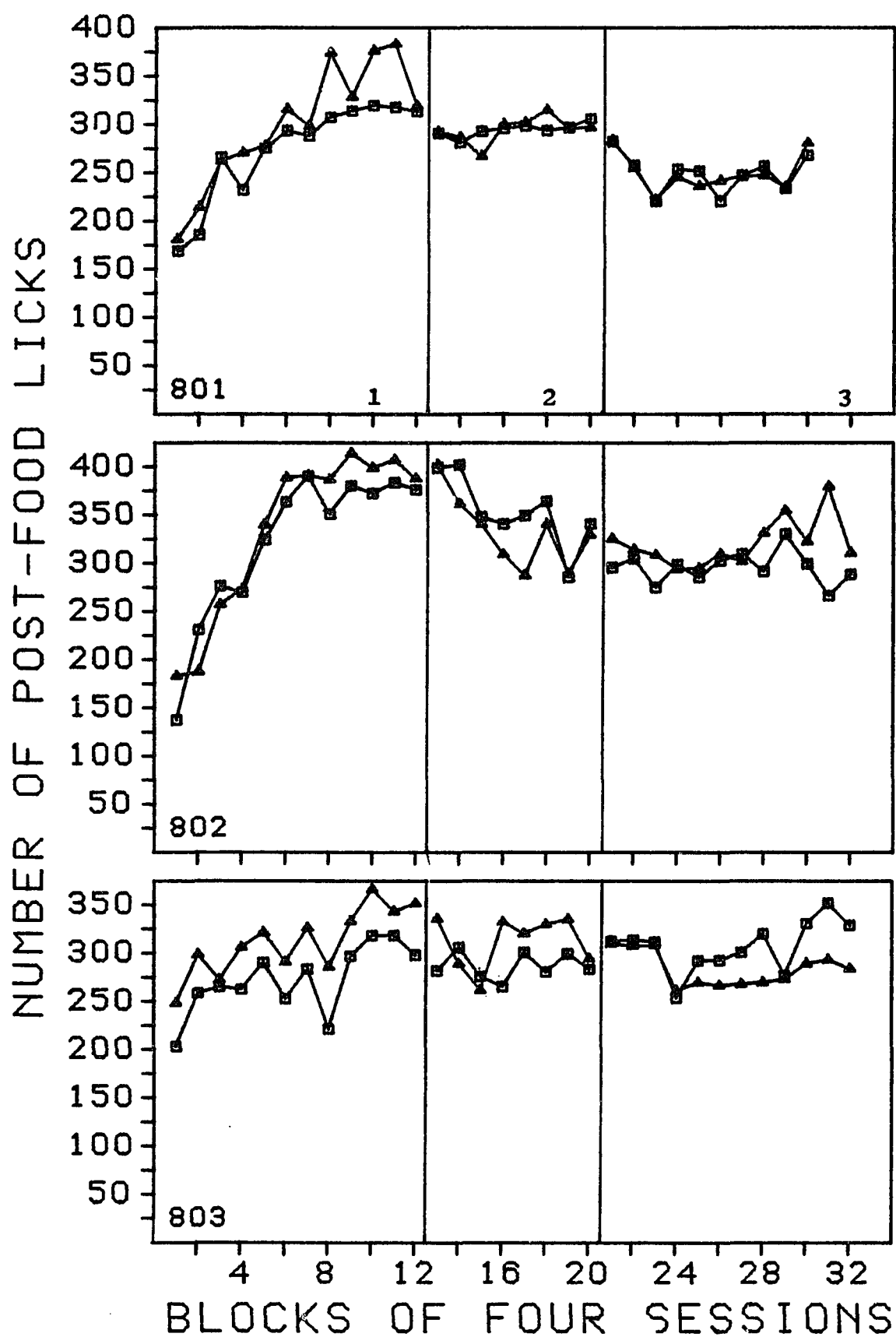




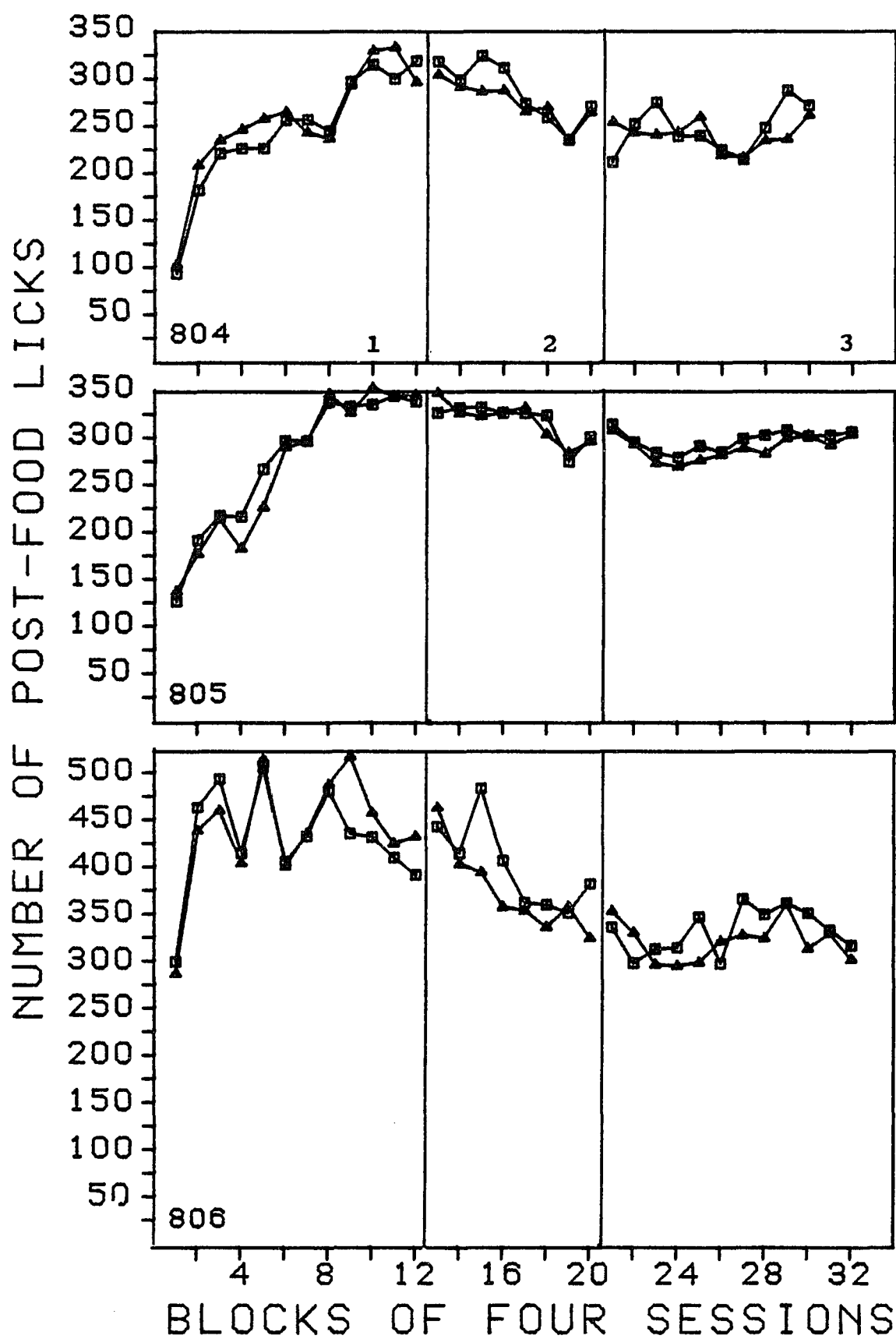
### Post-Food Drinking Levels

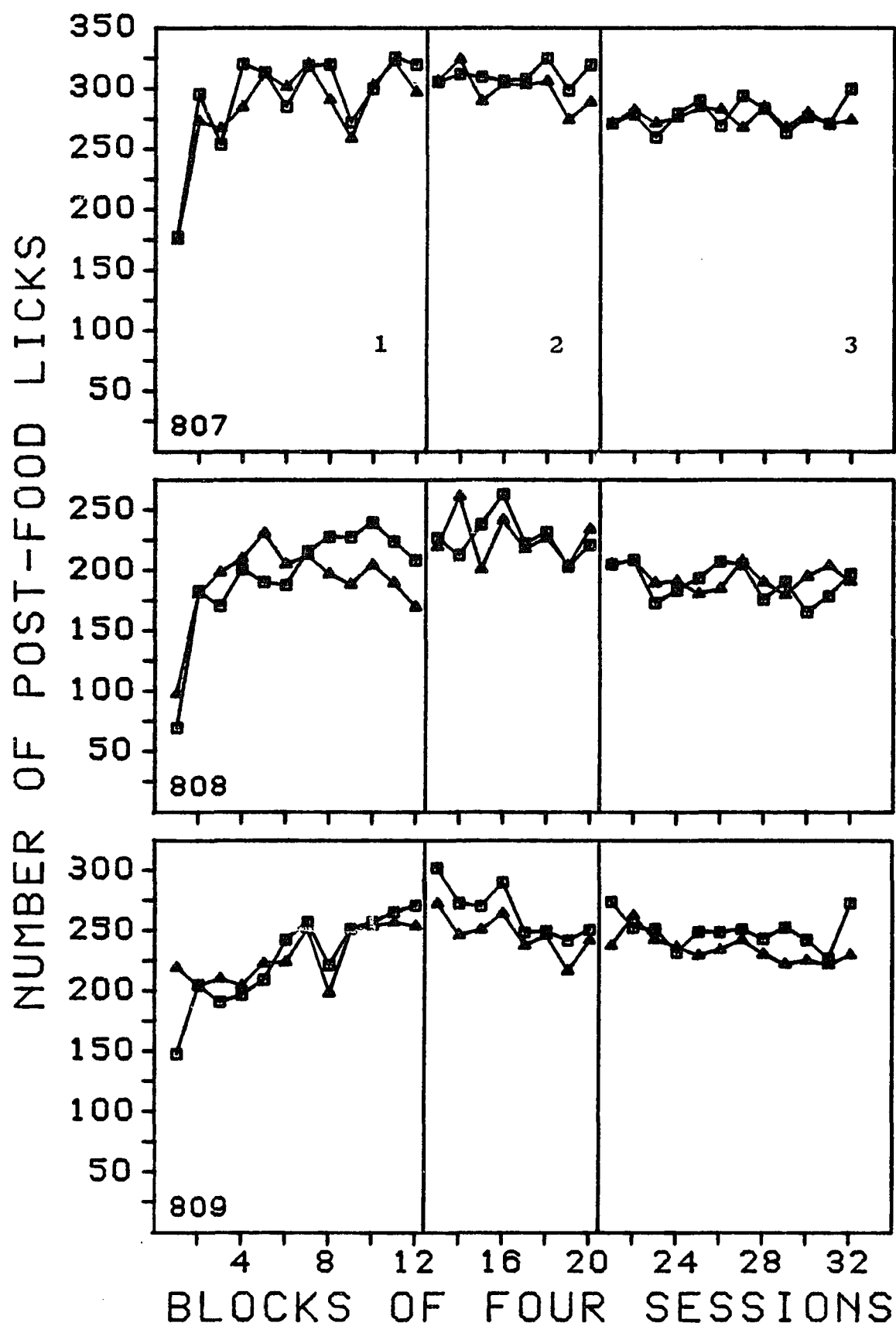
Figures 86 - 89. Data represent the mean number of licks per post-food component for all subjects. Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. For experimental animals (801 - 809) during Phases 1 and 3, and for control animals (811 and 812) during Phase 2, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations, while triangles represent behavior in the presence of the signal previously correlated with stimulus presentations. Signals were not presented to control animals during Phase 1. Squares represent average post-food behavior for control animals in Figure 61, and average post-stimulus behavior in Figure 64 during Phase 1 for those animals. For Subject 810, squares during Phase 2 represent behavior in the presence of the tone, while triangles represent behavior in the presence of the repetitive click, neither of which was correlated with component outcomes for that animal. Individual data points represent performance averaged over 4 consecutive sessions.

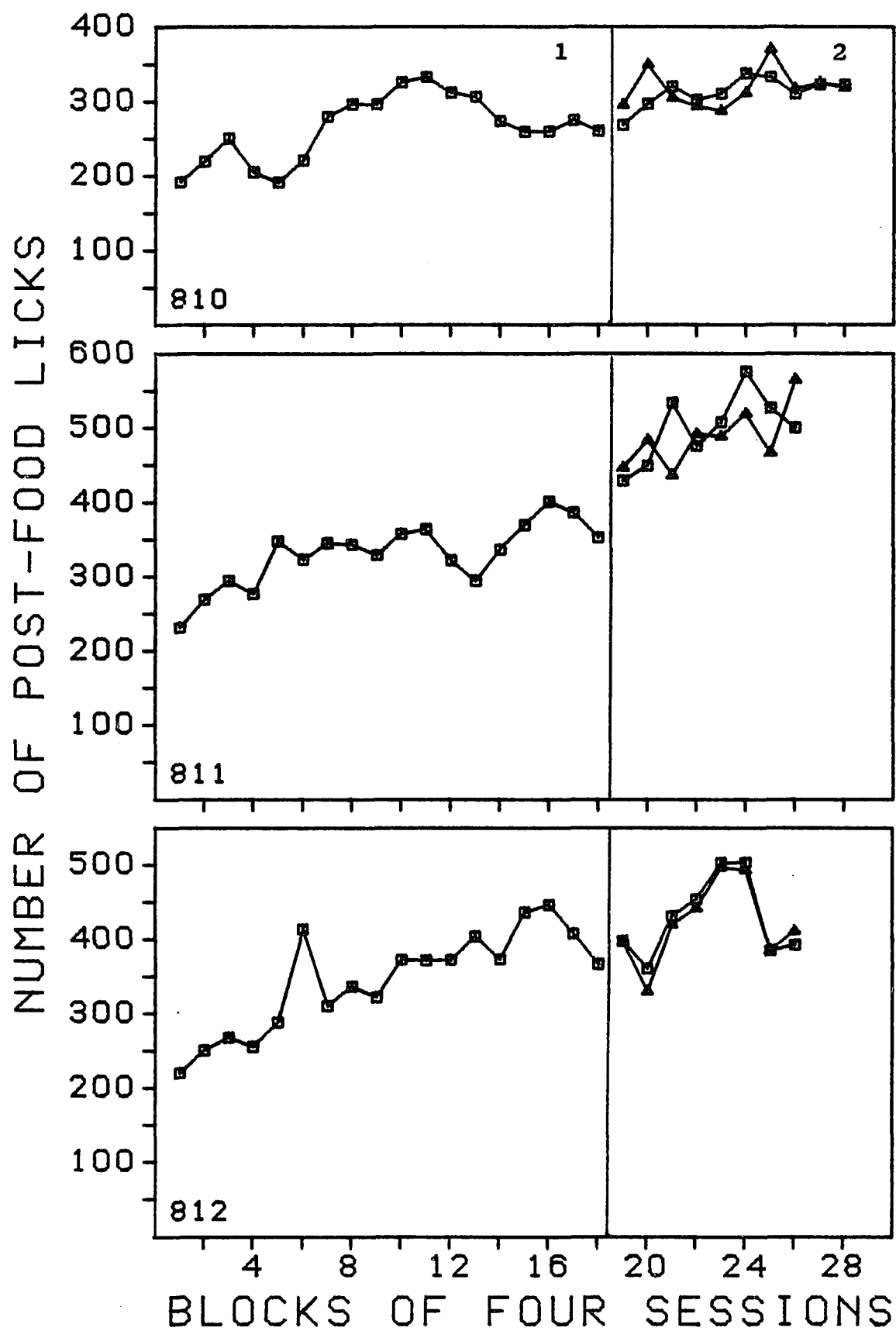
Asymptotic levels were achieved more quickly among experimental subjects (Figures 86 - 88) than among control subjects (Figure 89). Post-food drinking levels were generally not affected by changes in experimental conditions, nor were there consistent between-subjects differences between pre-food and pre-stimulus levels. Post-food levels exceeded post-stimulus levels for all subjects.









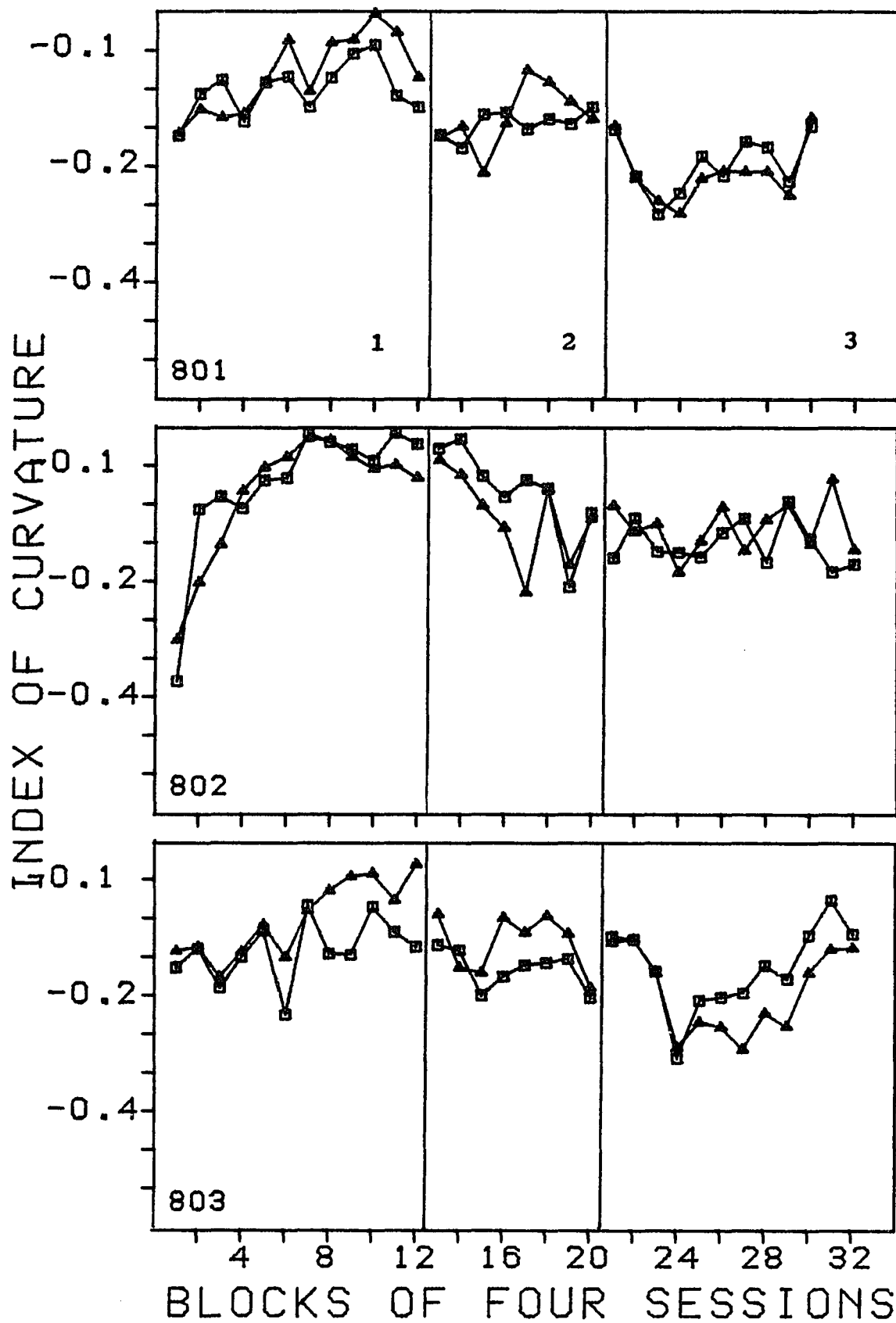


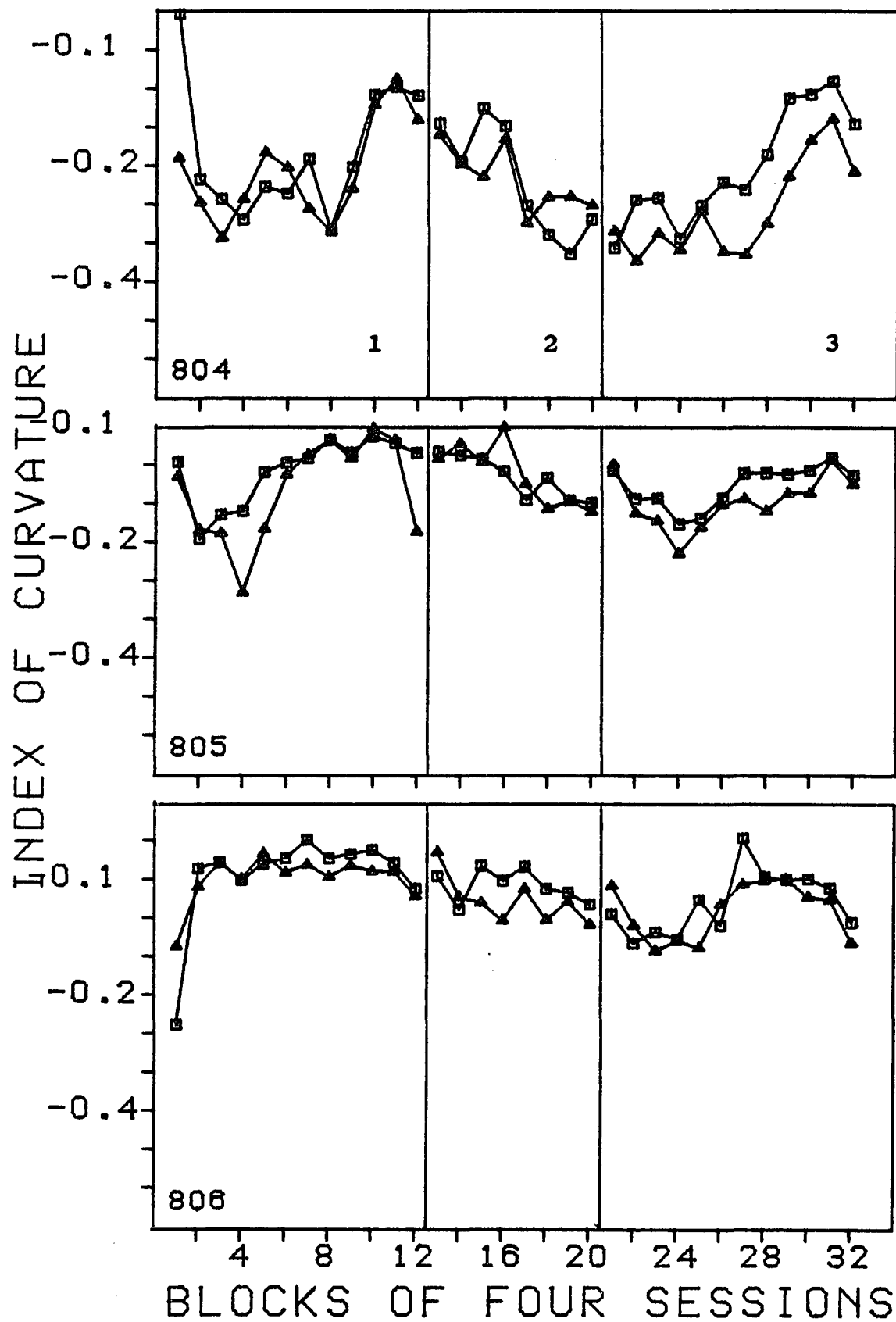
# Indices of Curvature:

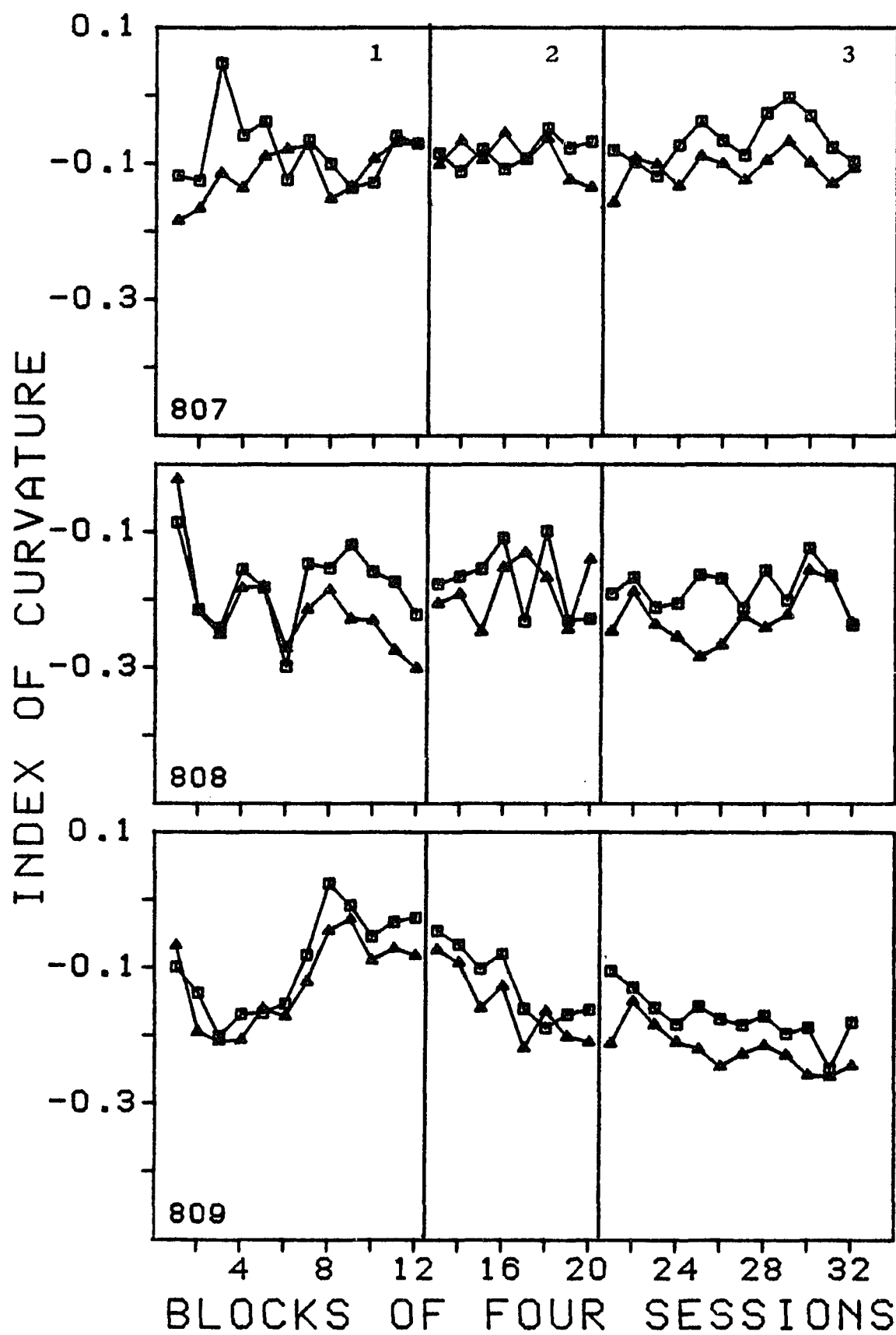
## Post-Food Licking

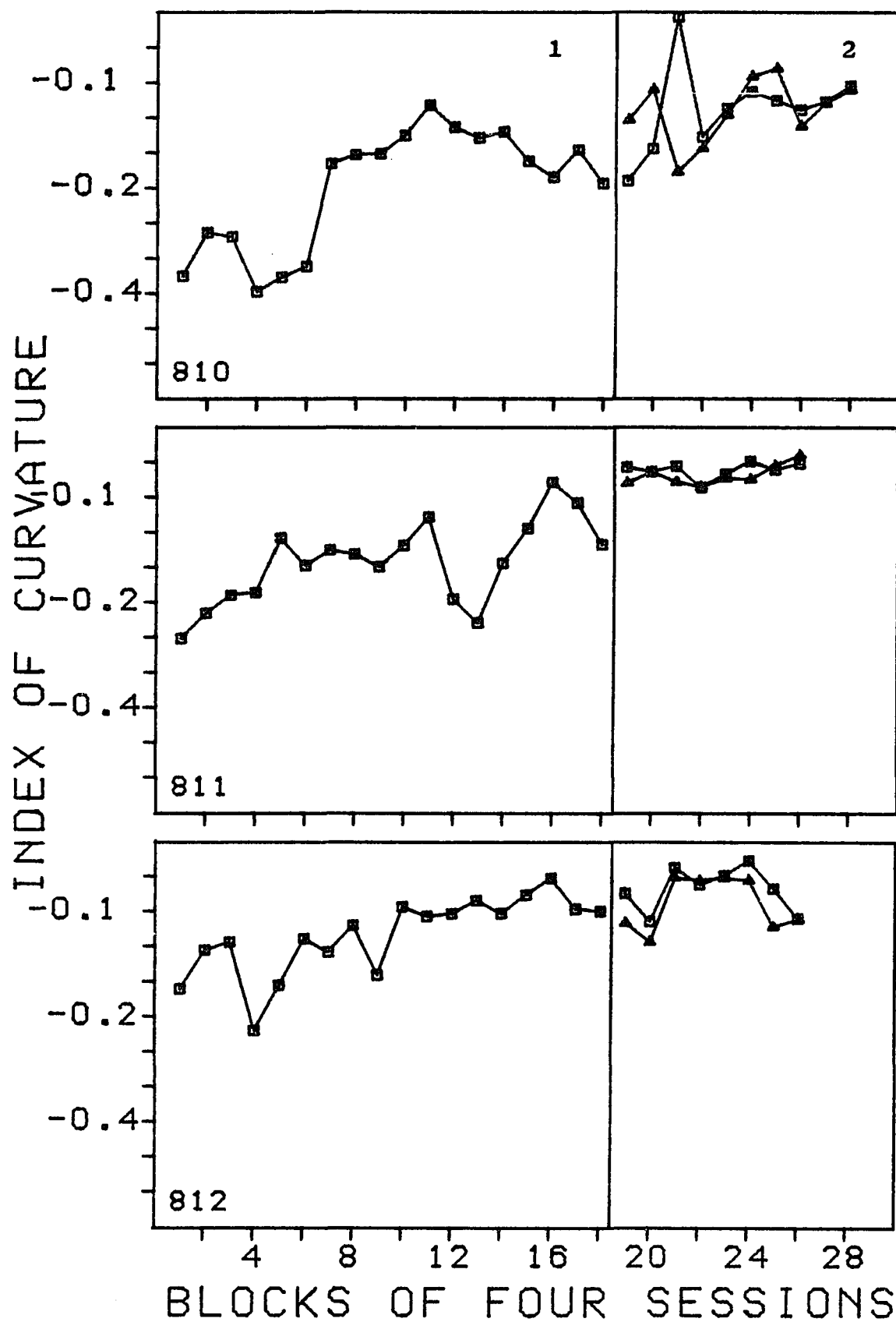
Figures 90 - 93. Data represent indices of curvature, as described under Method, which characterize post-food lick distributions for all subjects. Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. For experimental animals (801 - 809) during Phases 1 and 3, and for control animals (811 and 812) during Phase 2, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations, while triangles represent behavior in the presence of the signal previously correlated with stimulus presentations. Signals were not presented to control animals during Phase 1. Squares represent average post-food behavior for control animals in Figure 61, and average post-stimulus behavior in Figure 64 during Phase 1 for those animals. For Subject 810, squares during Phase 2 represent behavior in the presence of the tone, while triangles represent behavior in the presence of the repetitive click, neither of which was correlated with component outcomes for that animal. Individual data points represent performance averaged over 4 consecutive sessions.

Indices were generally negative, indicating that licking occurred at a higher rate during the first half than during the second half of post-food components. They did not differ reliably between pre-food and pre-stimulus components. Nor did they differ between experimental (801 - 809) and control (810 - 812) subjects, or between subjects in response-dependent (801 - 806, 810 - 812) and in response-independent (807 - 809) conditions. Post-food lick distributions were, in most cases, were not affected by changes in experimental conditions. What changes did accompany the transition from Phase 1 to Phase 2 presumably reflect the accompanying decrement in F2 drinking (figures 28 and 29), most of which typically occurred during the second half of components.







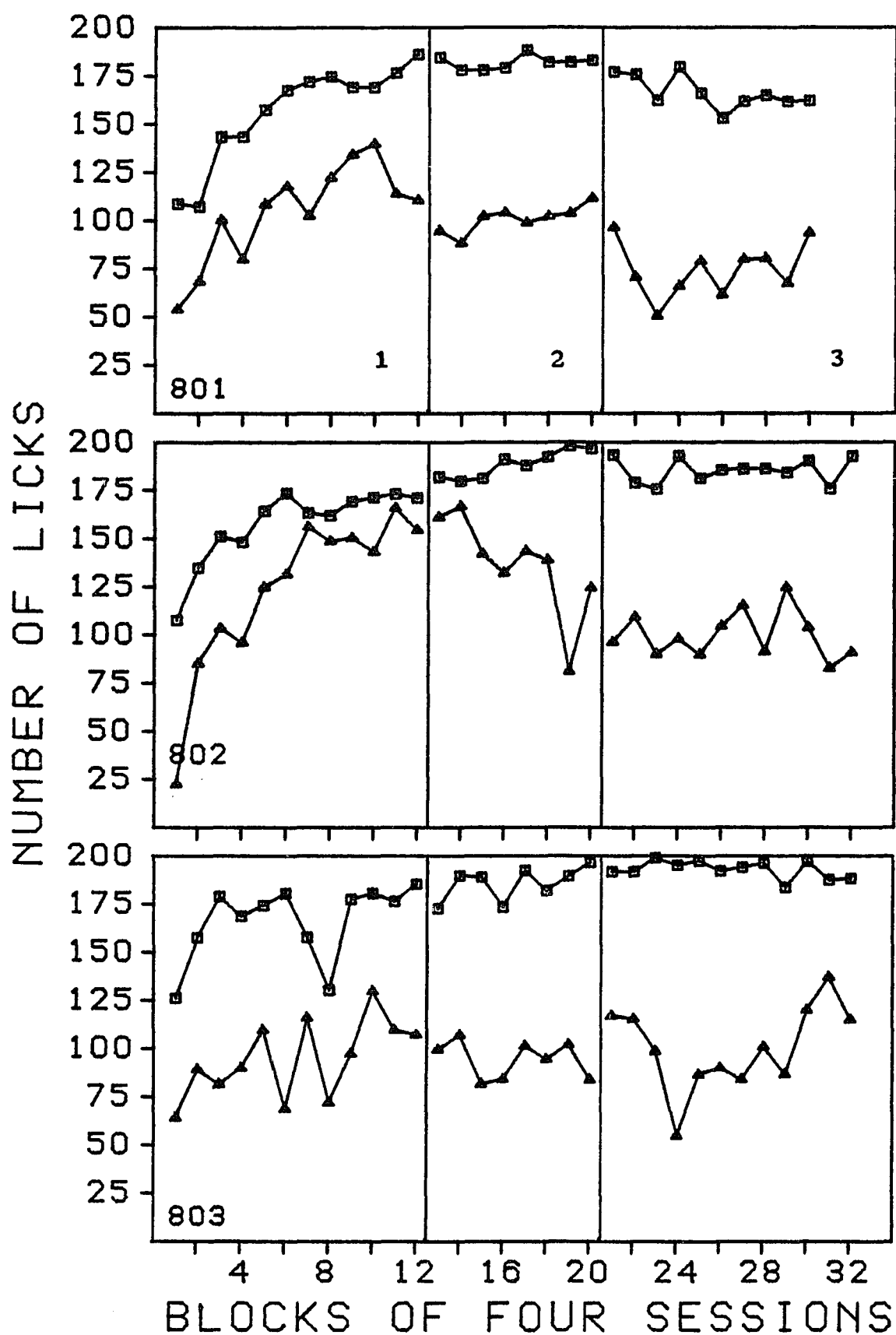


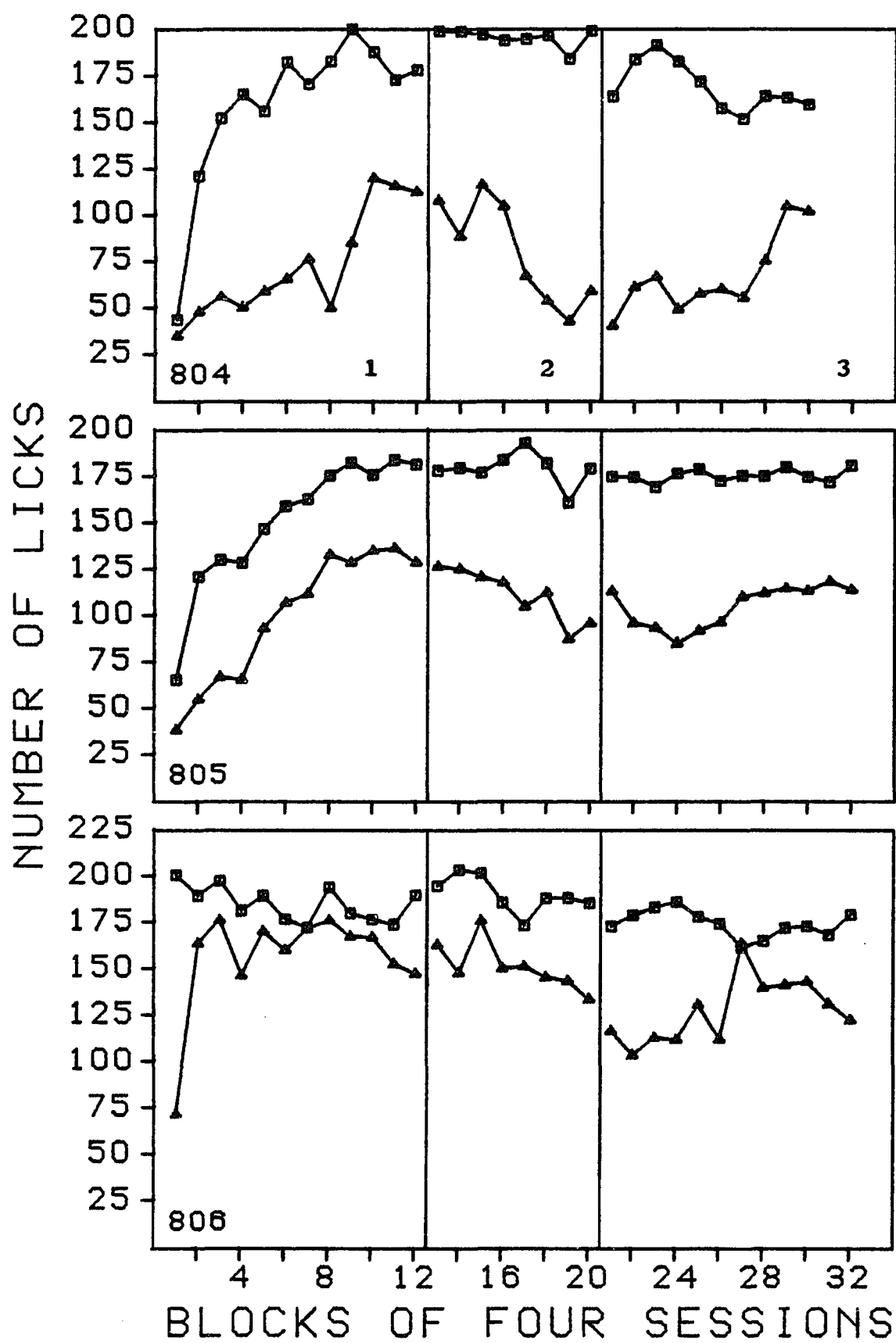


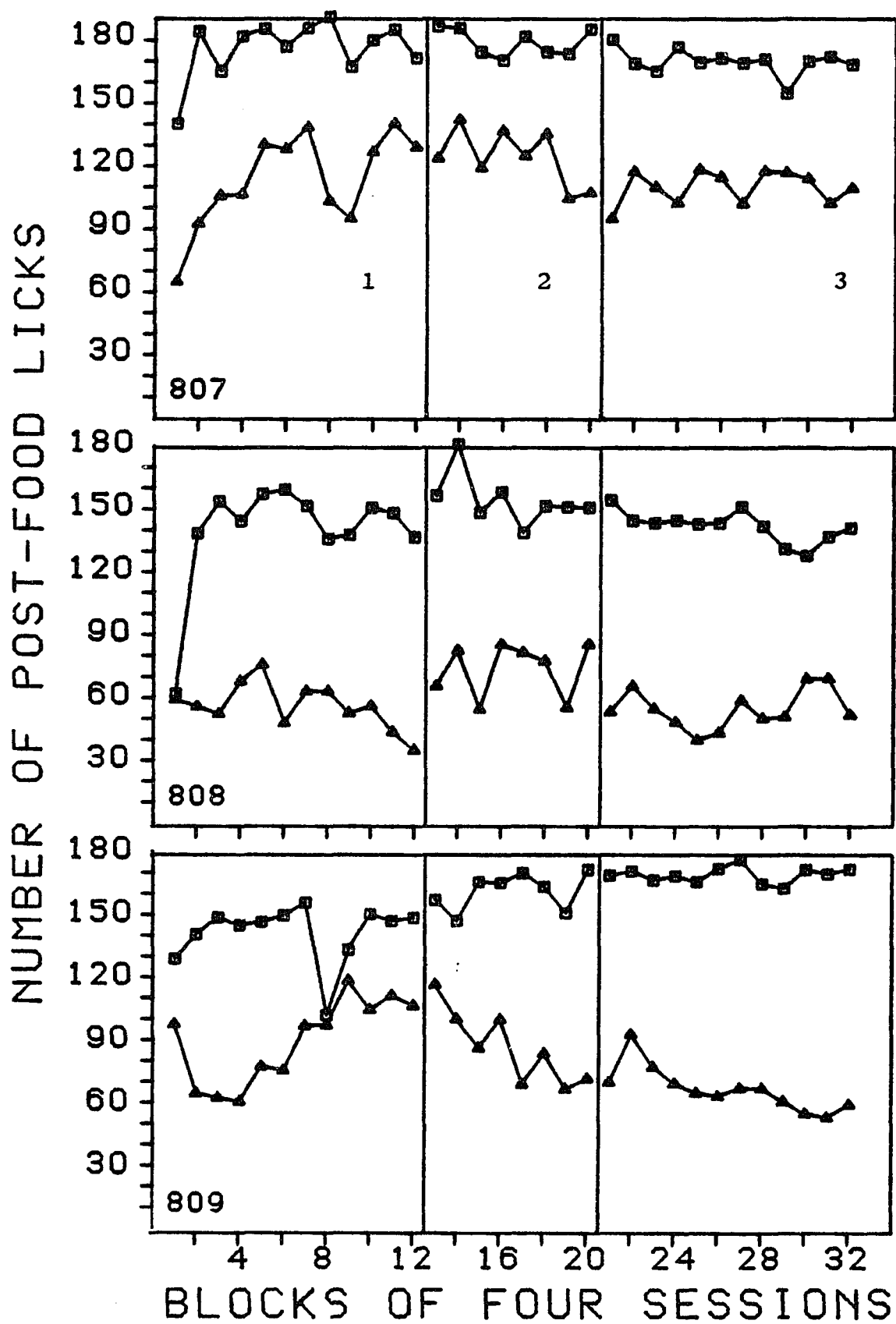
### Post-Food Lick Distributions

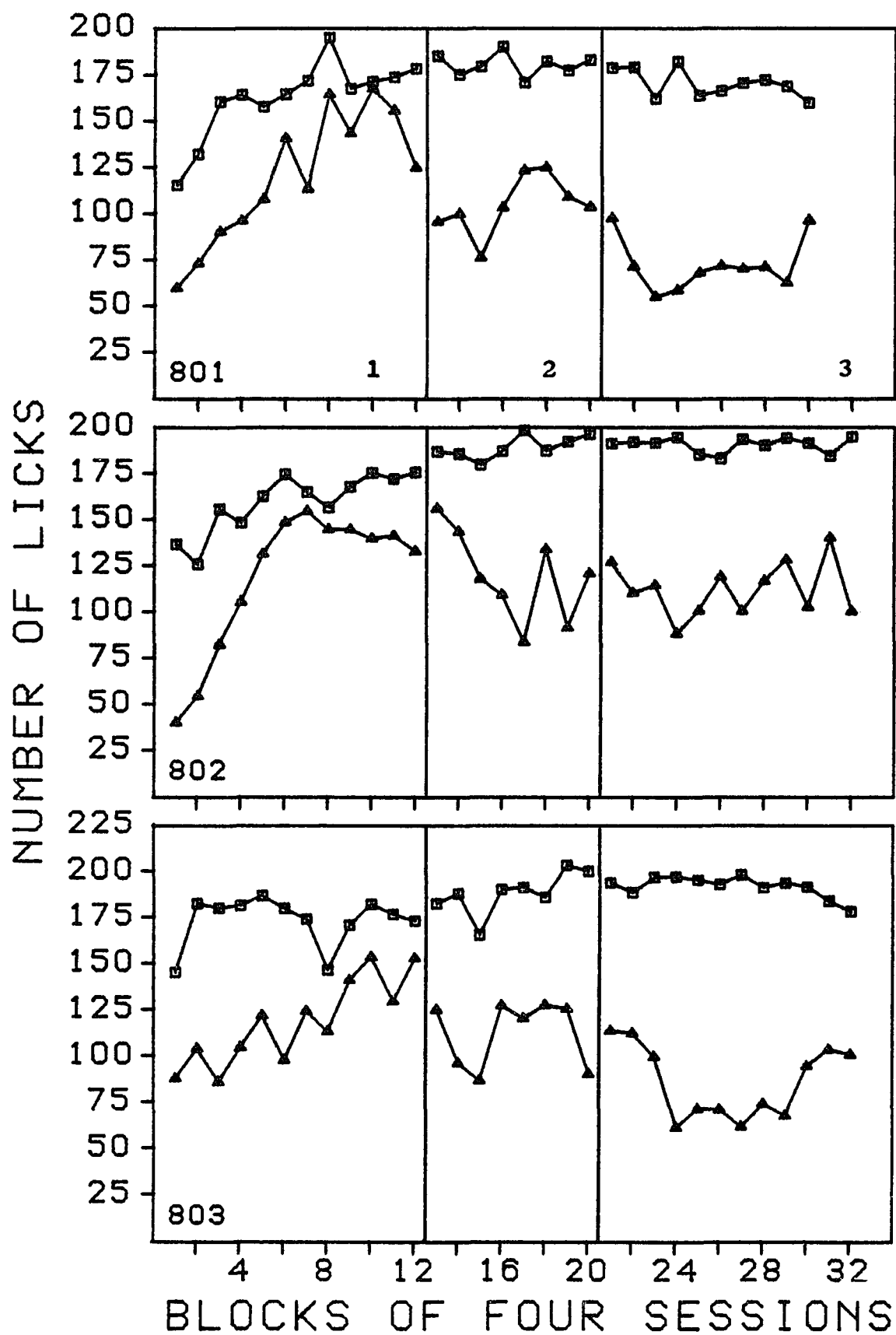
Figures 94 - 99. Data represent mean numbers of licks per post-food component, broken down according to whether they occurred during the first or the second half (35 sec) of components, for experimental subjects (801 - 809). Experimental phases, separated by vertical lines, are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. Within each figure, squares represent behavior during the first half of a component, and triangles represent behavior during the second half of a component. Individual data points represent performance averaged over 4 consecutive sessions.

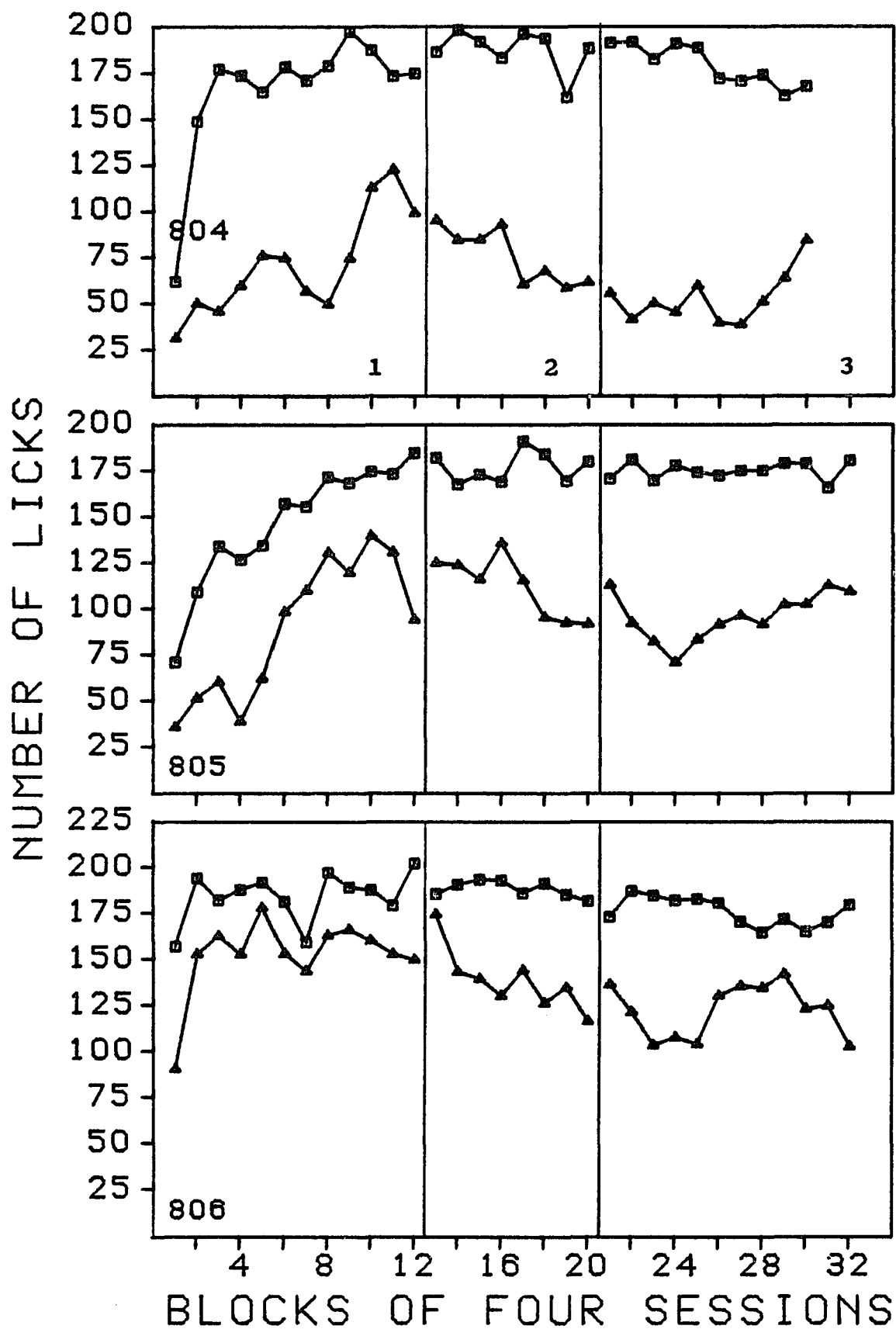
Lick distributions confirm indices of curvature in demonstrating that licking typically occurred at a higher rate during the first half than during the second half of post-food components.

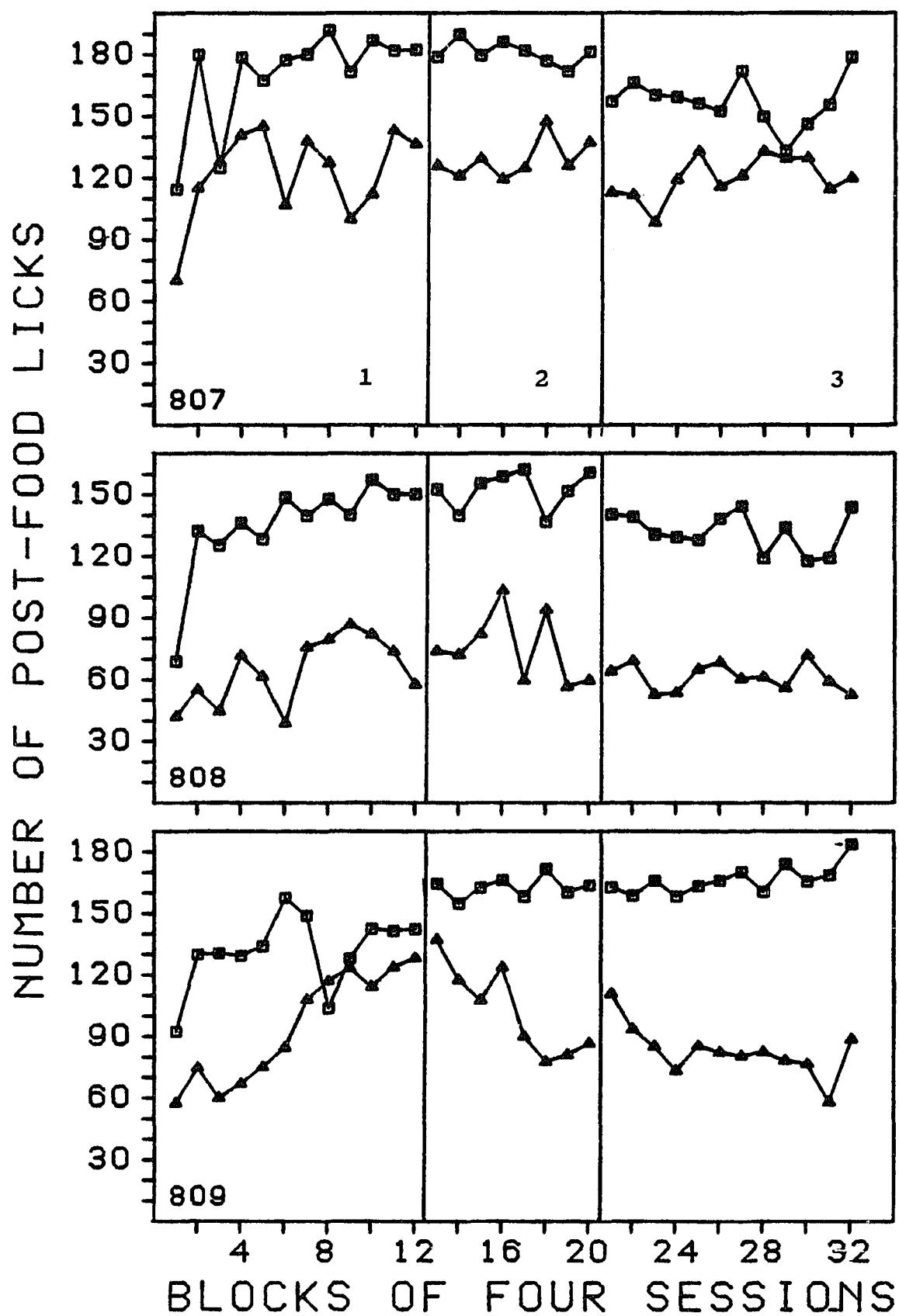










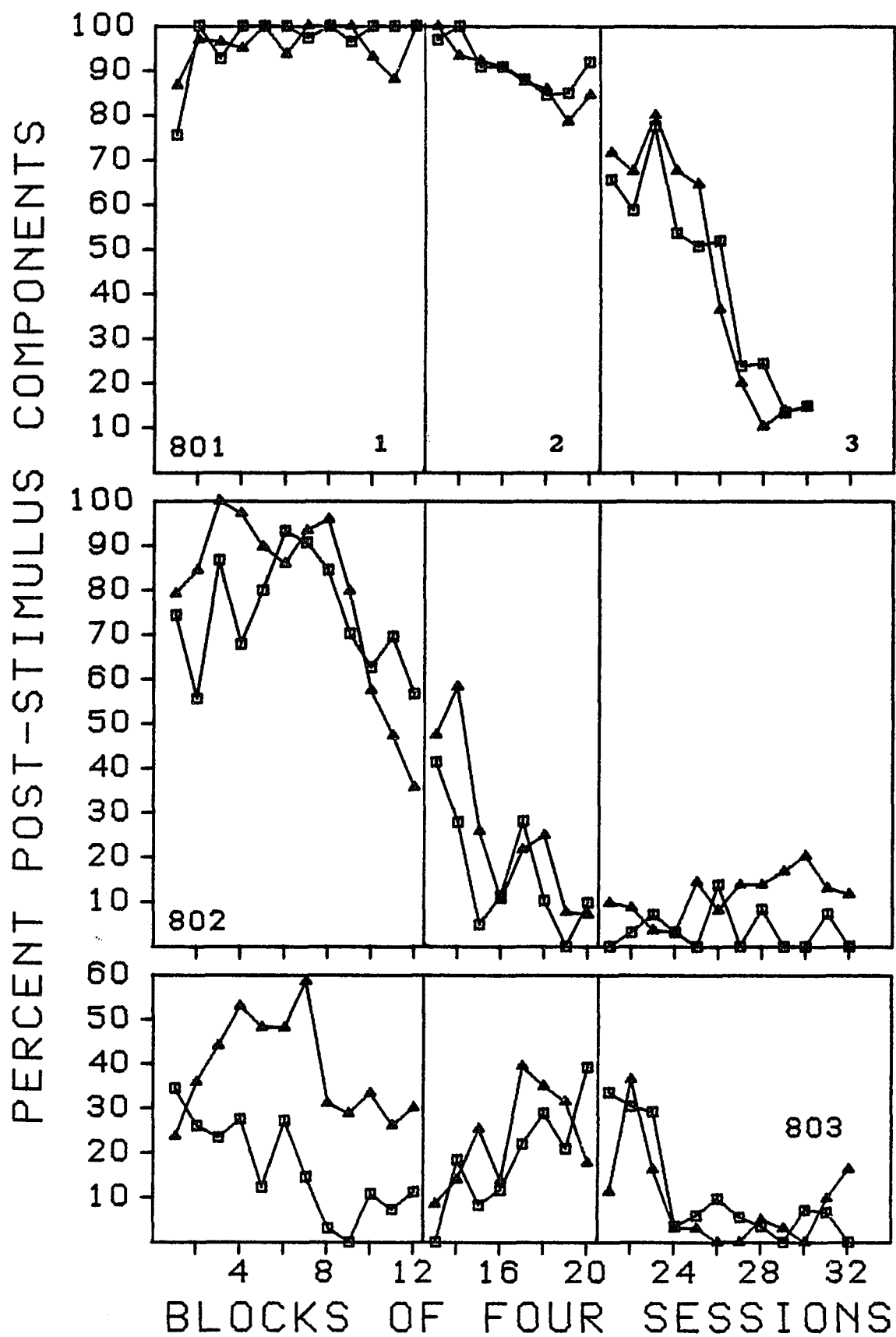


### Incidence of Post-Stimulus Drinking

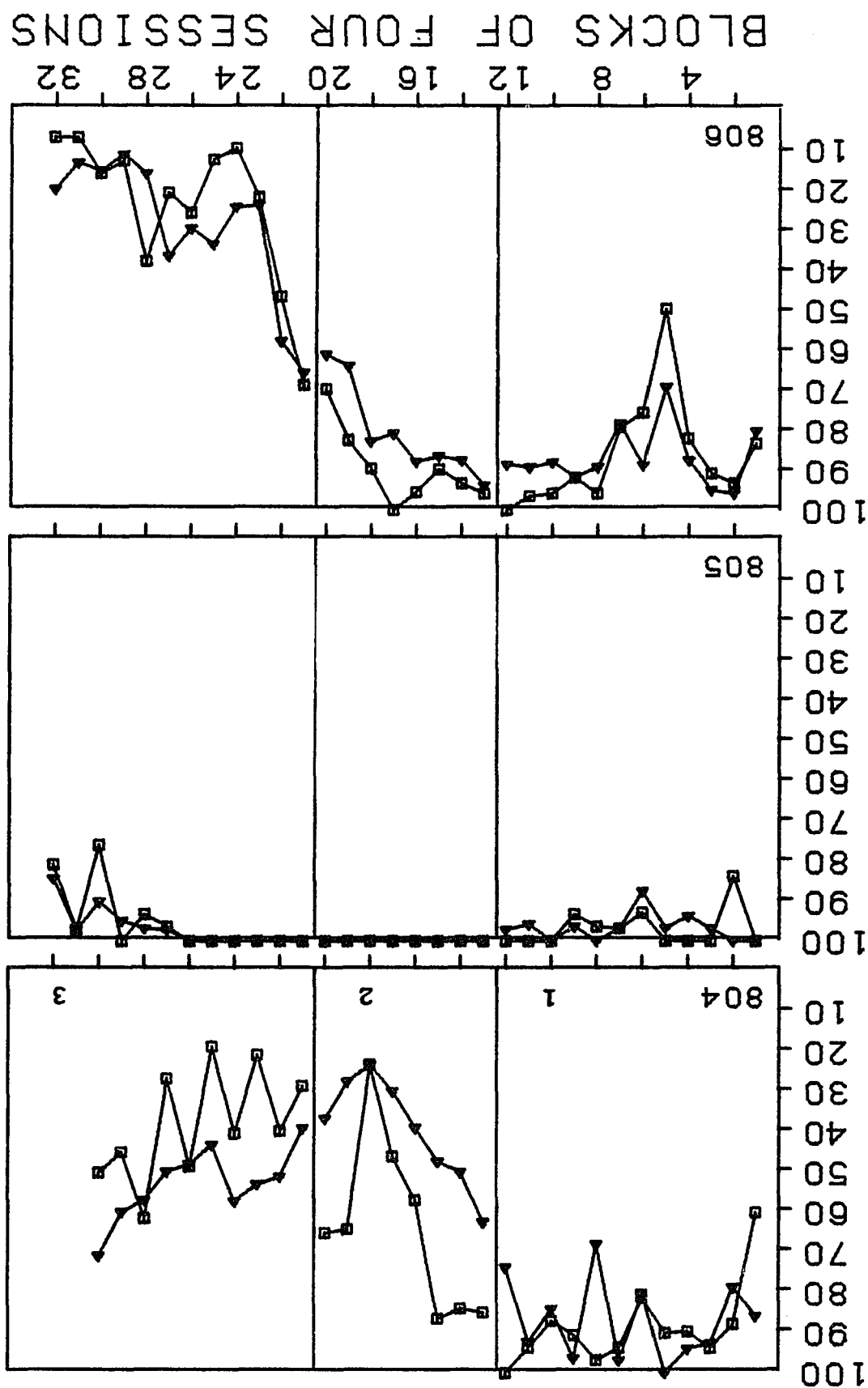
Figures 100 - 102. Data represent the percentage of post-stimulus components during which at least 1 lick bout occurred, for all experimental subjects (801 - 809). Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-food behavior, while triangles represent pre-stimulus behavior. During Phase 2, squares represent behavior in the presence of the signal previously correlated with food presentations, while triangles represent behavior in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.

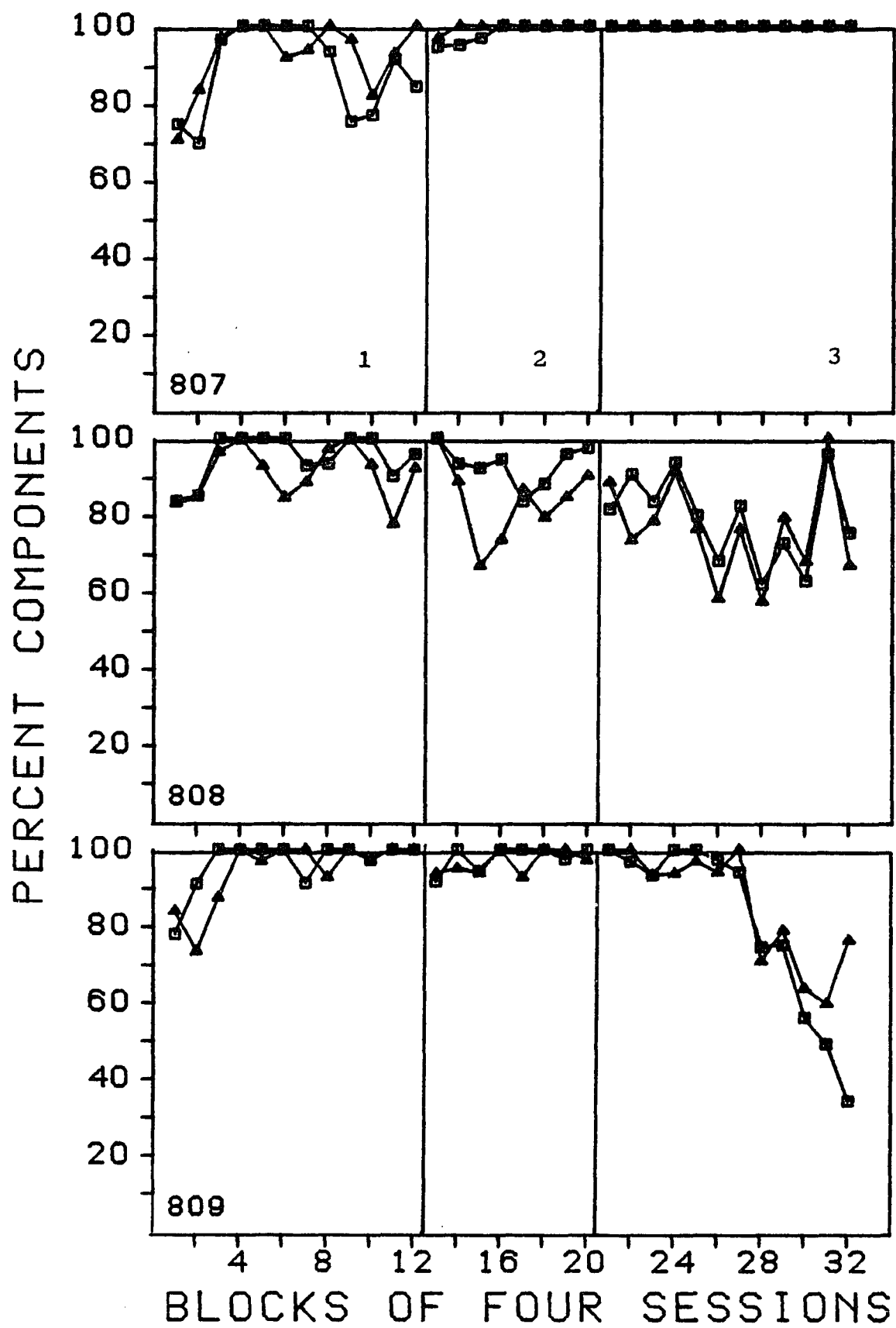
The incidence of post-stimulus drinking typically reached a higher asymptote among experimental subjects (excluding #803), than among control subjects (see Figure 50, post-Sn components). The incidence of post-stimulus drinking declined in 4 cases (801, 803, 804, 806) upon removal of the signal-outcome correlation in Phase 2. A further decline was generally evident among those 4 subjects upon the start of Phase 3, and recovery of Phase 1 levels did not occur.





# PERCENT POST-STIMULUS COMPONENTS

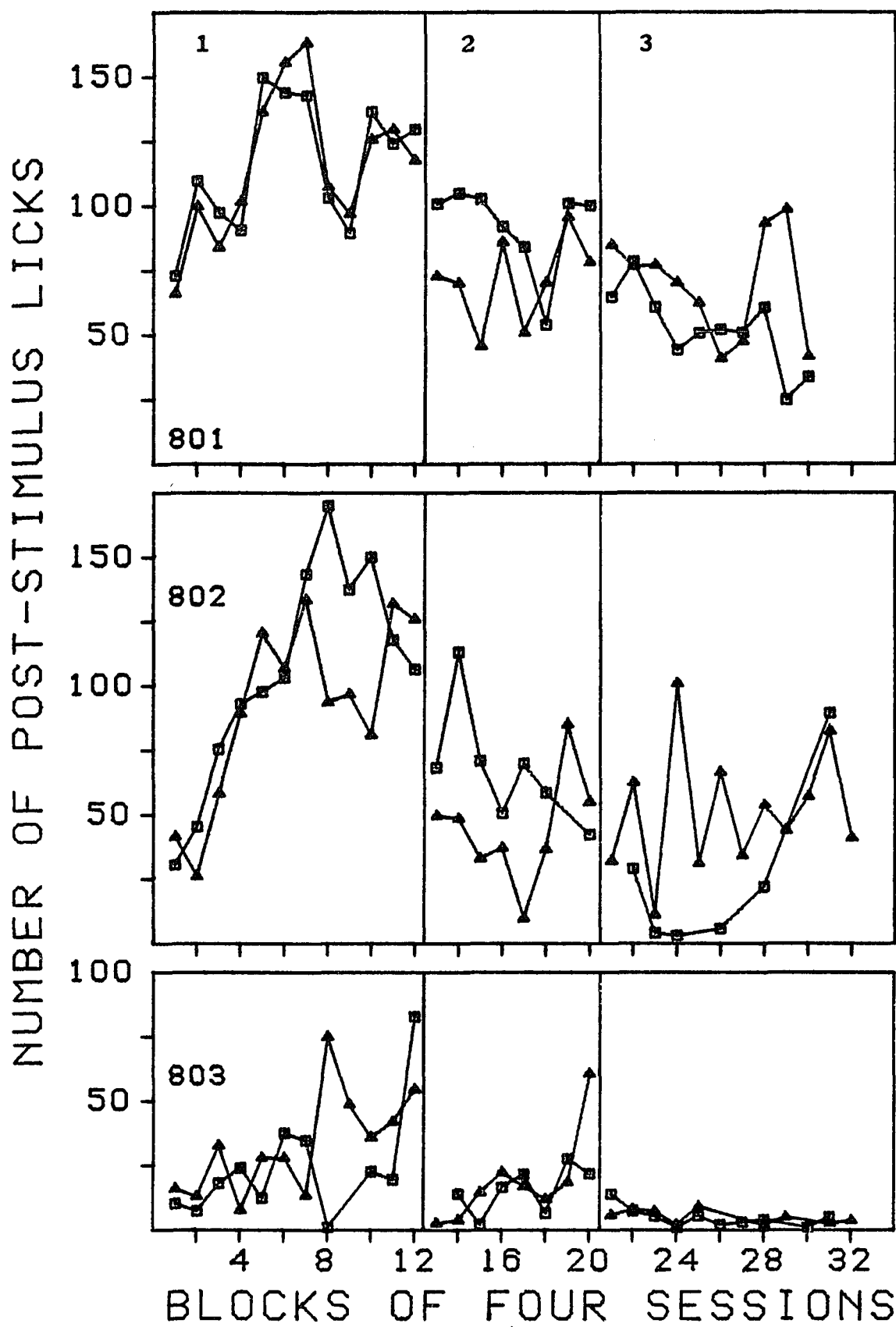


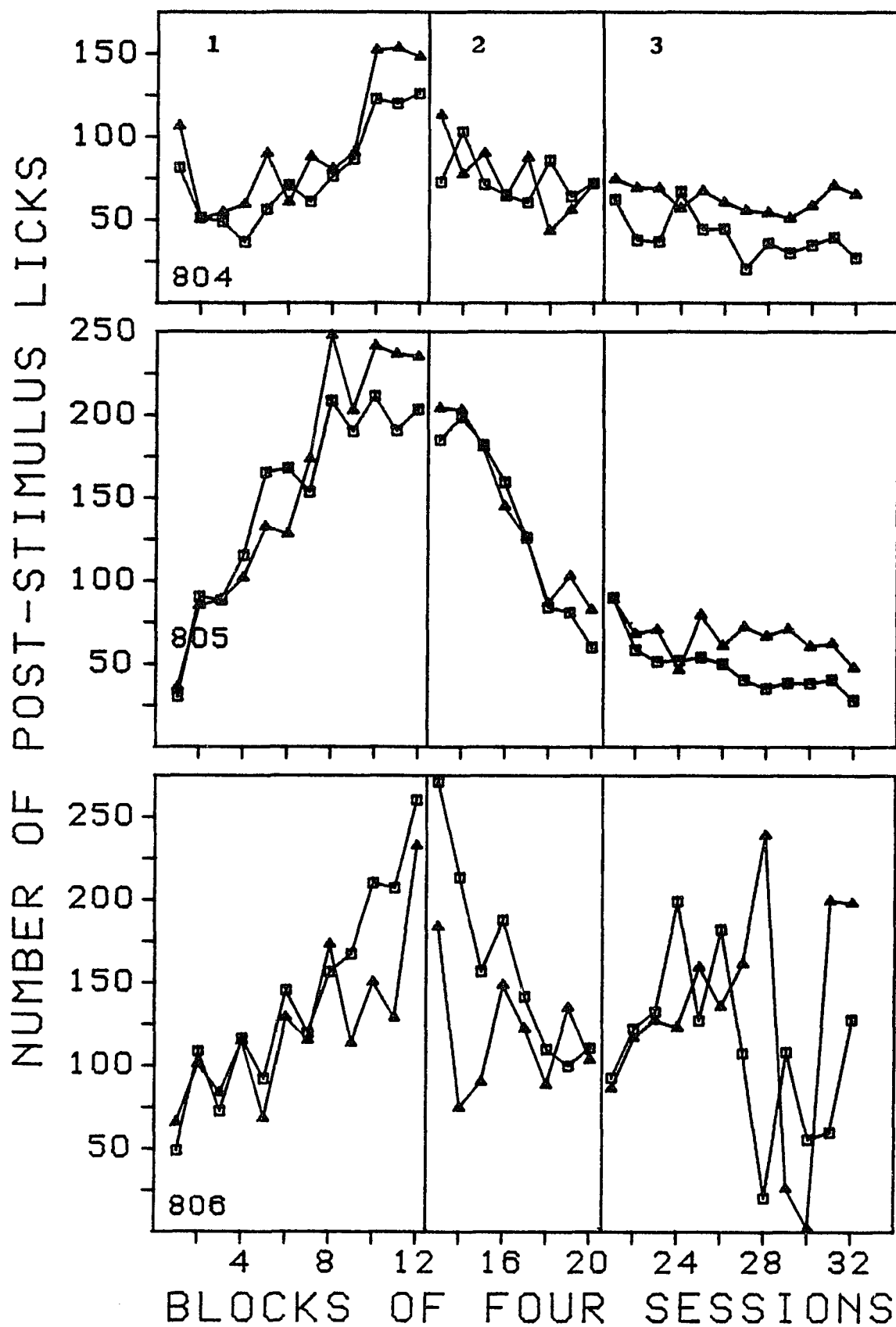


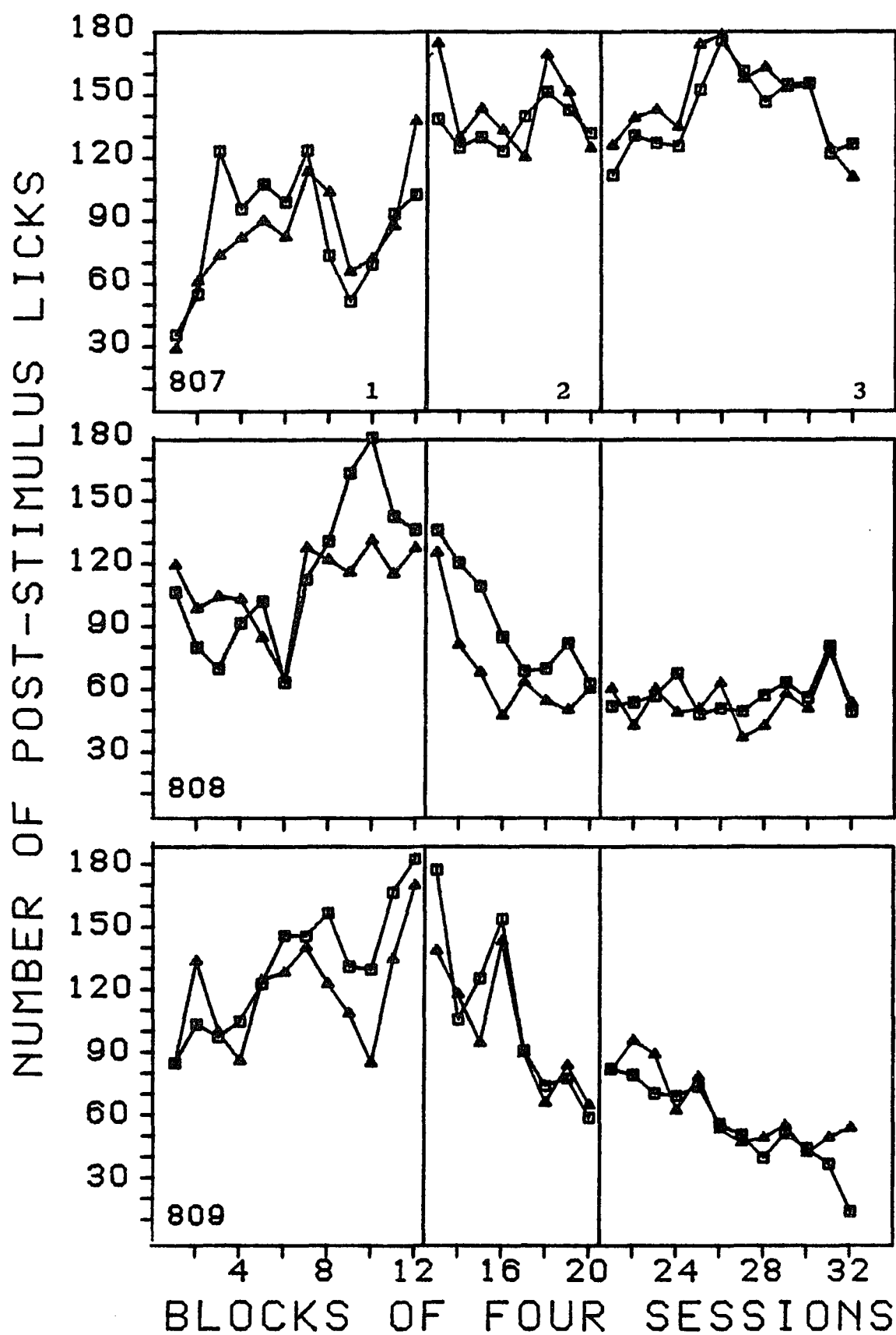
### Post-Stimulus Drinking Levels

Figures 103 - 105. Data represent the mean number of licks per post-stimulus component during which at least one lick bout occurred, for experimental subjects (801 - 809). Experimental phases are separated by vertical lines and are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. During Phases 1 and 3, squares represent pre-food components, while triangles represent pre-stimulus components. During Phase 2, squares represent components in the presence of the signal previously correlated with food presentations, while triangles represent components in the presence of the signal previously correlated with stimulus presentations. Individual data points represent performance averaged over 4 consecutive sessions.

Comparison with Figure 51 will show that post-stimulus drinking levels among experimental animals exceeded those among control animals. Levels among subjects for which lever-pressing was not required (Figure 105) did not differ from those among subjects for which lever-pressing was required (Figures 103 and 104). There were no consistent between-subjects differences between pre-food and pre-stimulus levels. The transition from Phase 1 to Phase 2 was accompanied by an abrupt drop in post-stimulus levels for 5 of the 6 subjects for which lever-pressing was required. The decline was more gradual for the 6th response-dependent subject and for 2 of the response-independent subjects (808 and 809). Drinking levels did not recover to Phase 1 levels during Phase 3.







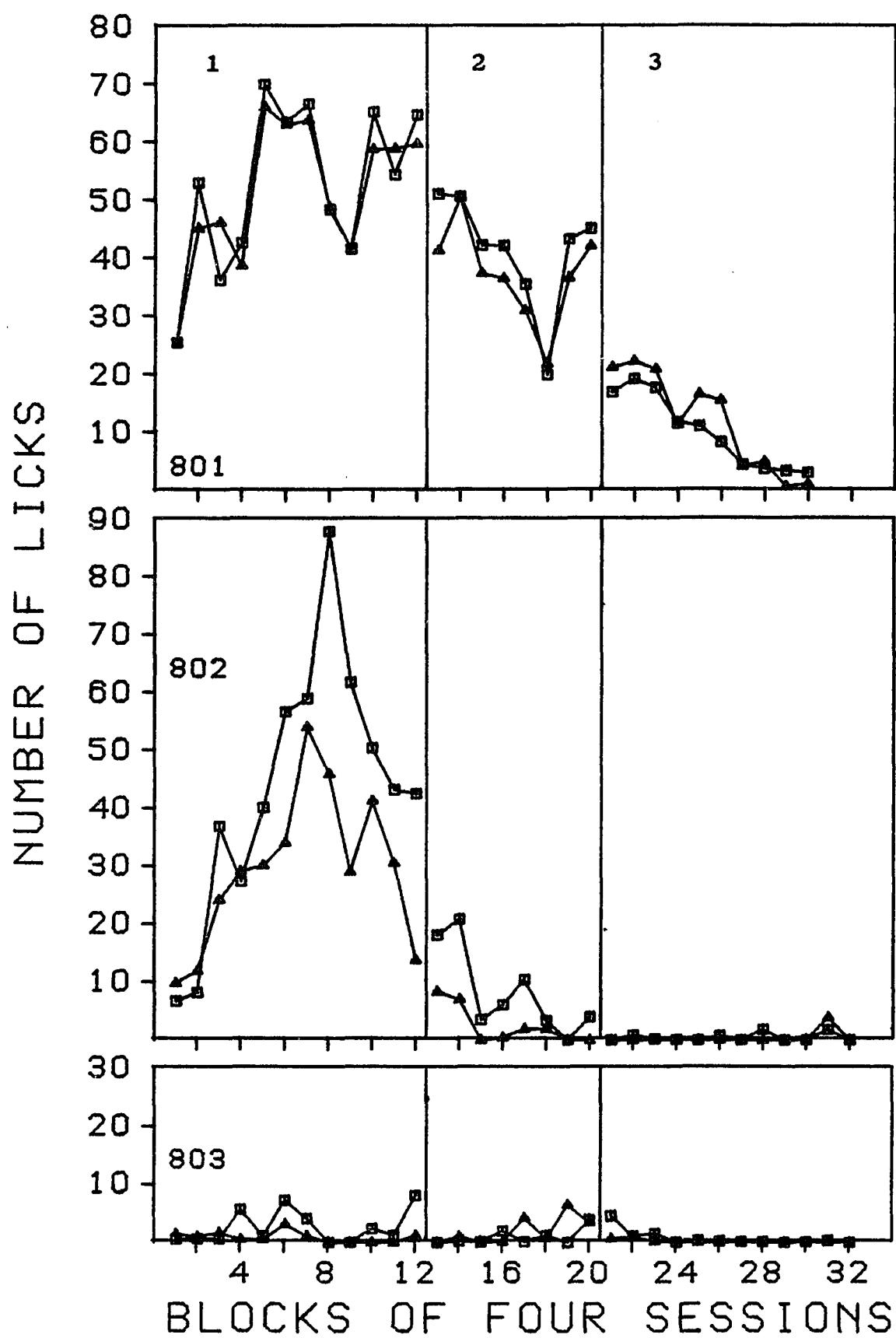
### Post-Stimulus Lick Distributions

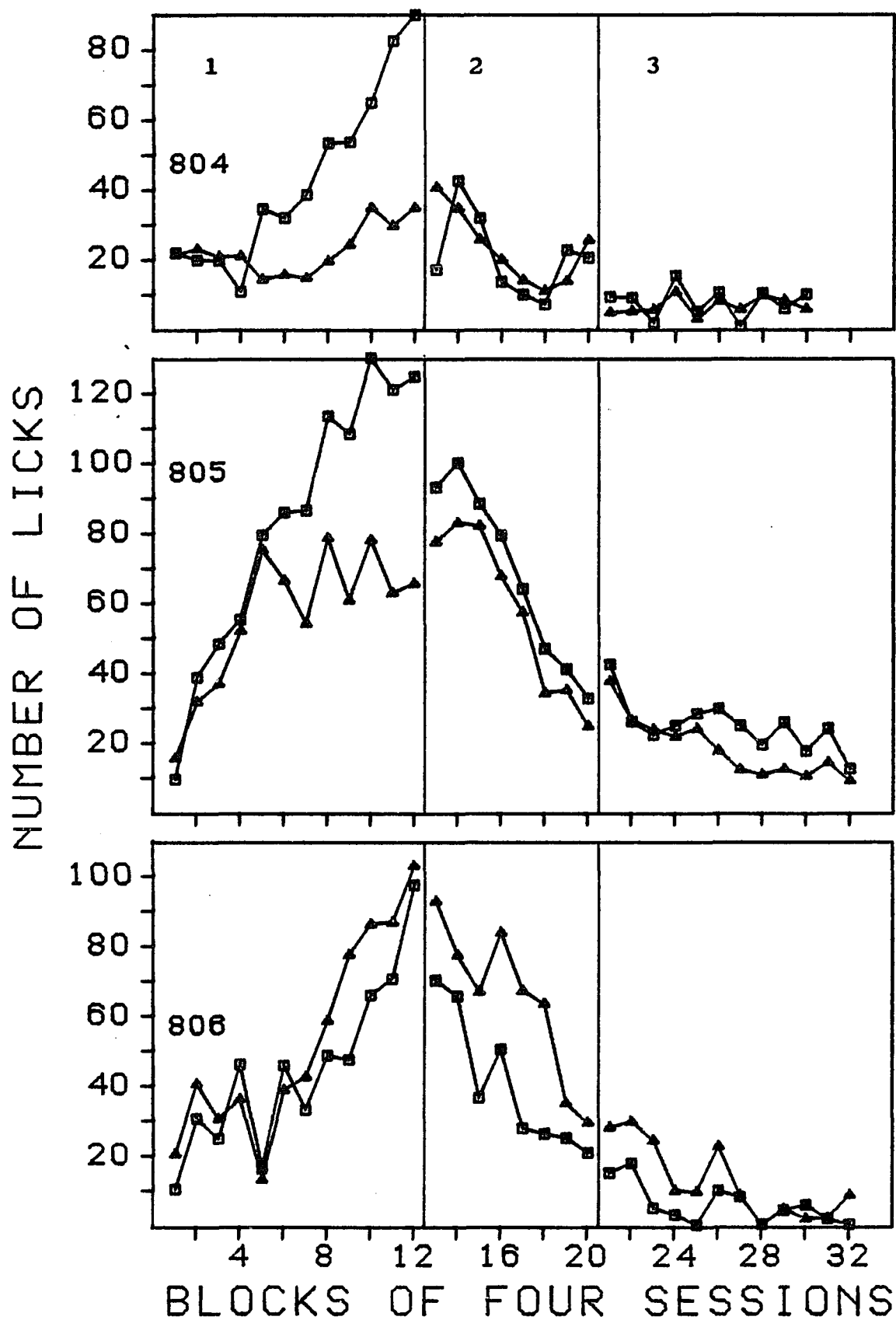
Figures 106 - 111. Data represent the mean number of licks per post-stimulus component, broken down according to whether they occurred during the first or the second half (35 sec) of components, for experimental subjects. Pre-foed (FS) distributions are presented in Figures 106 - 108, while pre-stimulus (SS) distributions are presented in Figures 109 - 111. Experimental phases, separated by vertical lines, are identified by 1-digit numbers. Individual subjects are identified by 3-digit numbers. Within each figure, squares represent behavior during the first half of a component, and triangles represent behavior during the second half of a component. Individual data points represent performance averaged over 4 consecutive sessions.

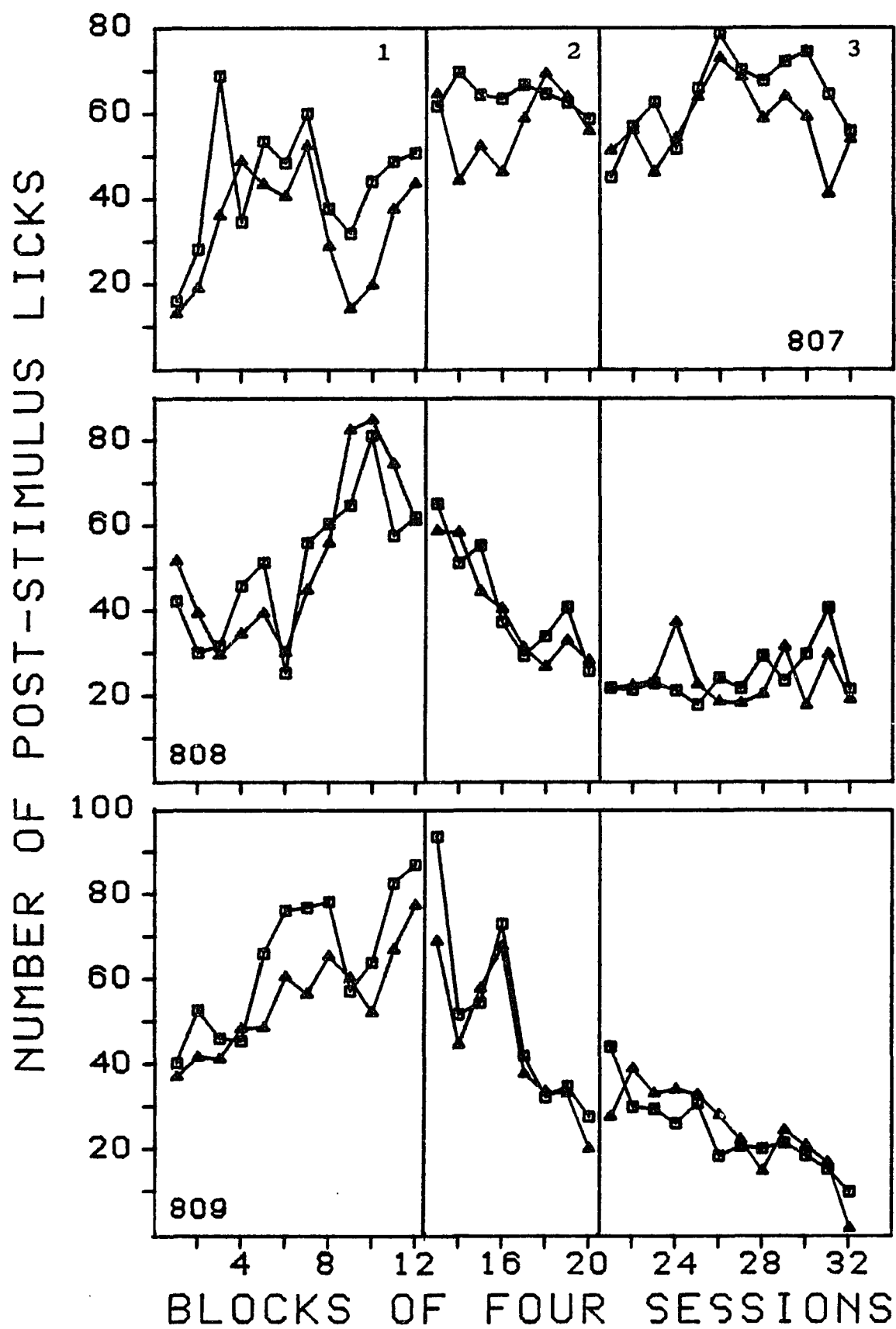
There were 6 cases (802 - 805, 807, 809) in which a similarity between FS patterns and post-foed patterns (Figures 94 - 99) was evident, such that licking occurred at a higher rate during the first half than during the second half of FS components. There was only 1 case (806) in which a pattern opposite that of post-foed components was consistently maintained during the FS components of Phase 1. FS patterns evident at the conclusion of Phase 1 generally disappeared during Phase 2, and were recovered in only 2 cases (805, 807) during Phase 3.

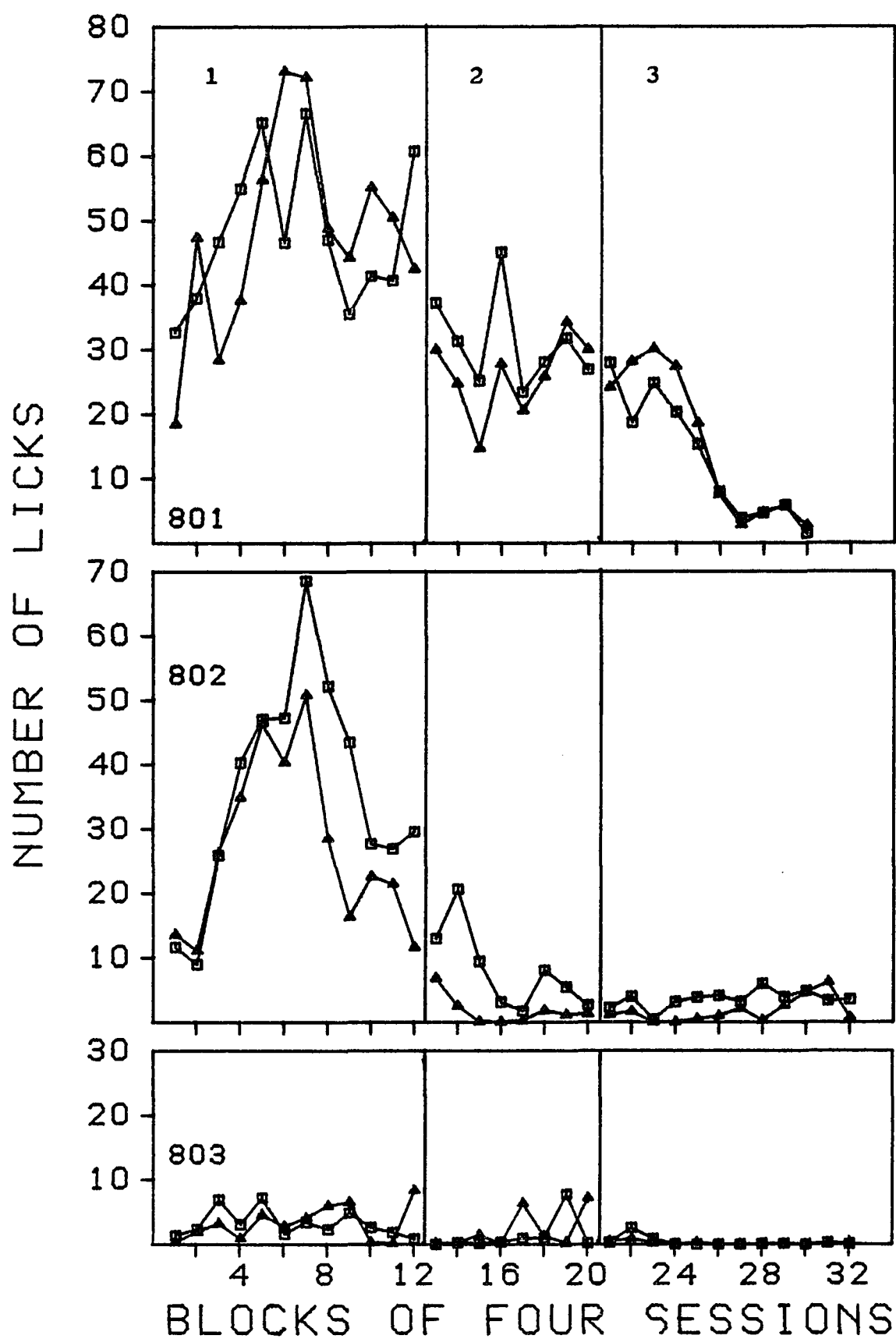
In only 1 case (802) did the SS pattern resemble typical post-foed patterns at the conclusion of Phase 1. In all other cases, the patterns suggested an even distribution of licks within SS components. Phase 2 FS distributions resembled typical SS distributions.

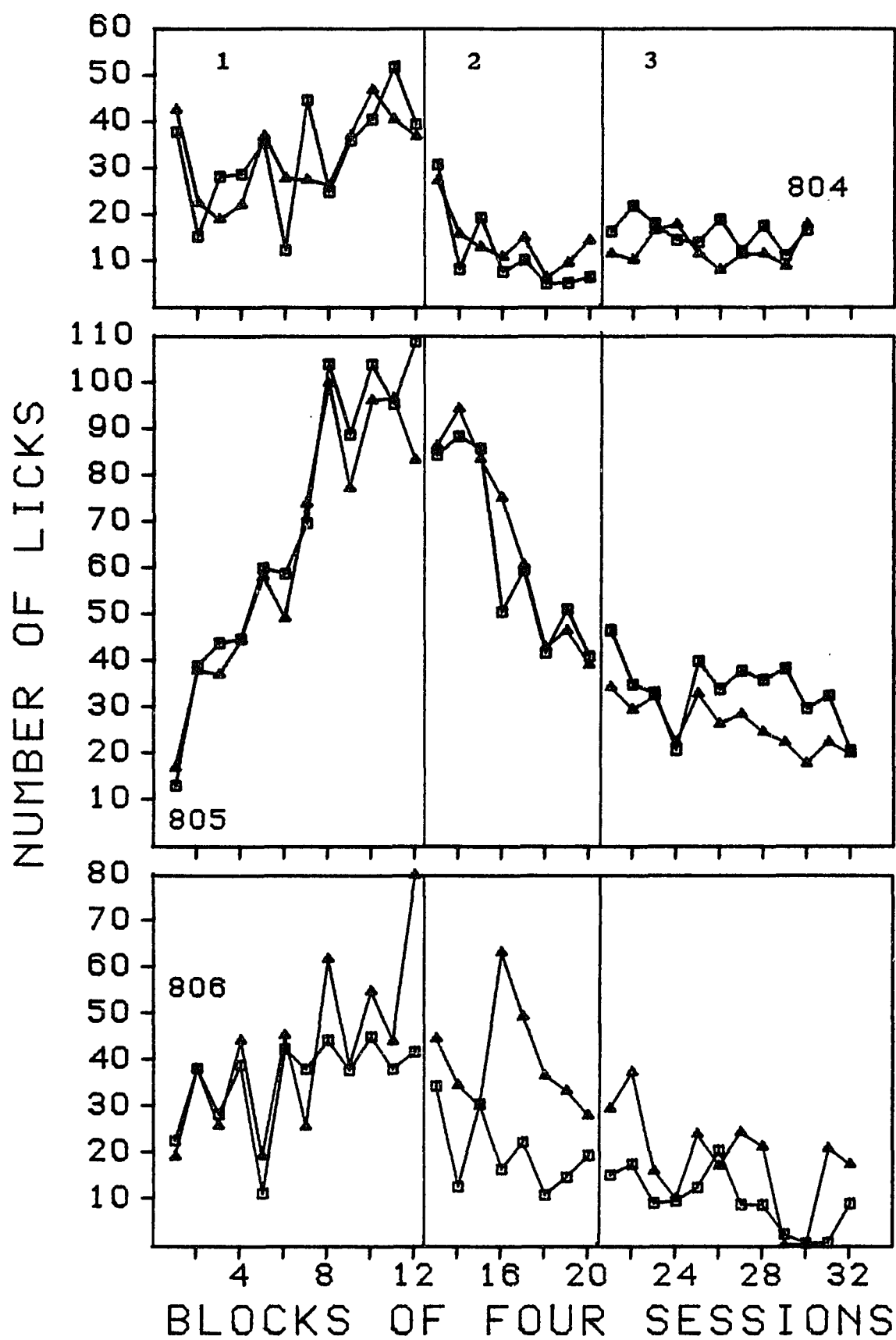


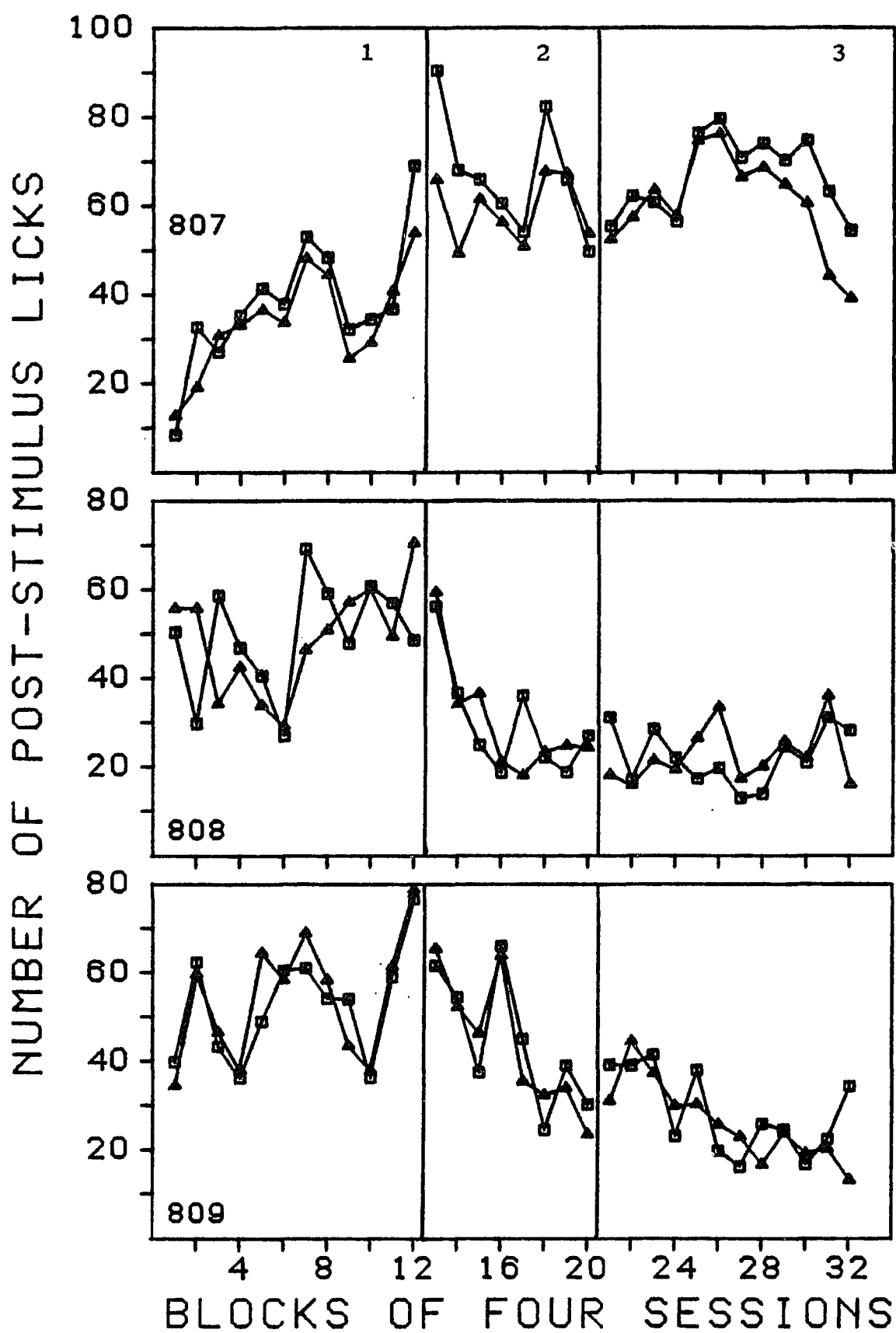












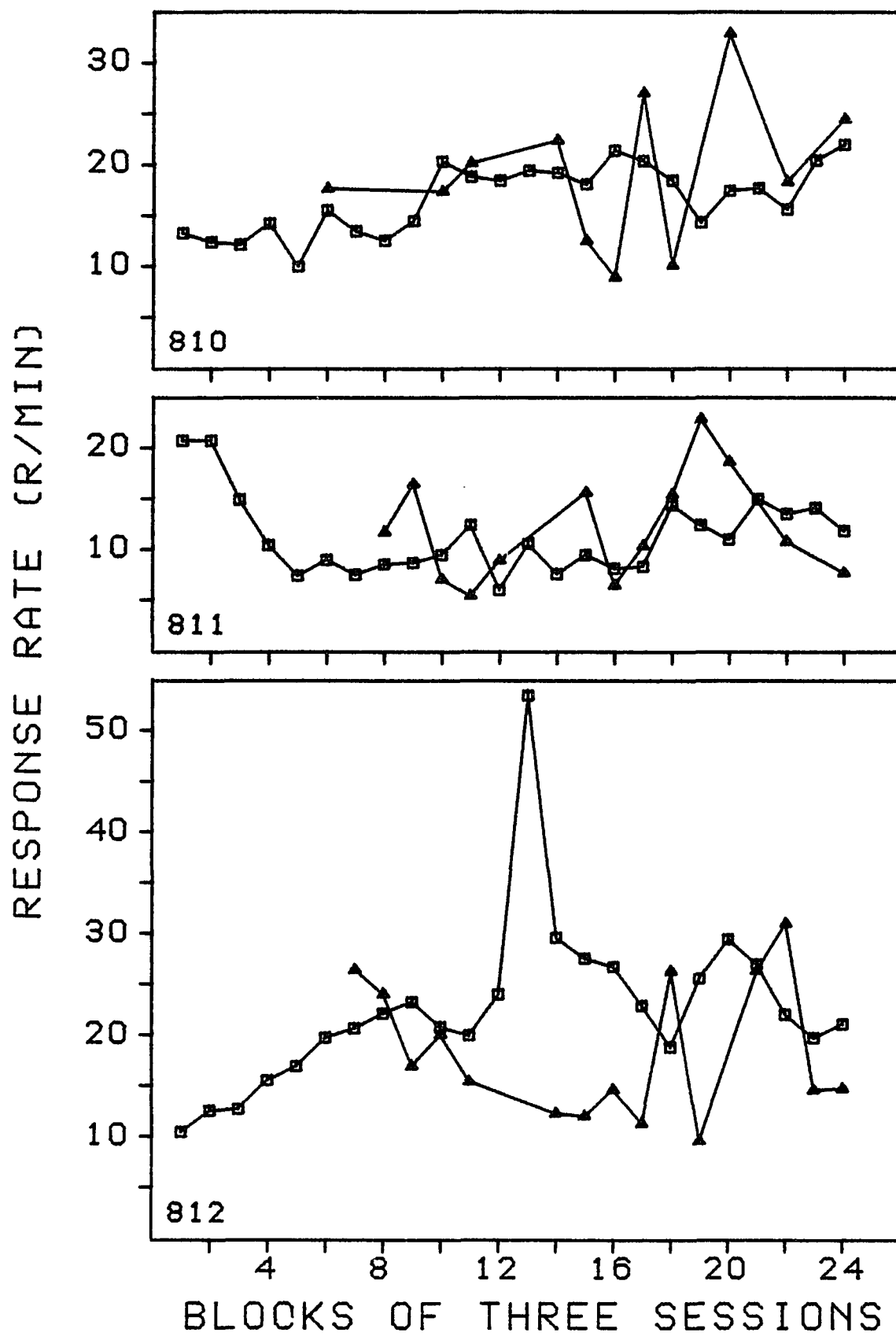
E. ADDITIONAL RESULTS OF EXPERIMENT 3

Post-Stimulus Response Rates

Figure 112. Data represent running lever-press rates, as described under General Methods, for the 3 subjects used in Experiment 3. Three-digit numbers identify individual subjects. Squares represent post-Sn behavior, and triangles represent post-Sp behavior. Individual data points represent performance averaged over 3 consecutive sessions.

There were no consistent differences between post-Sp and post-Sn lever-press rates.



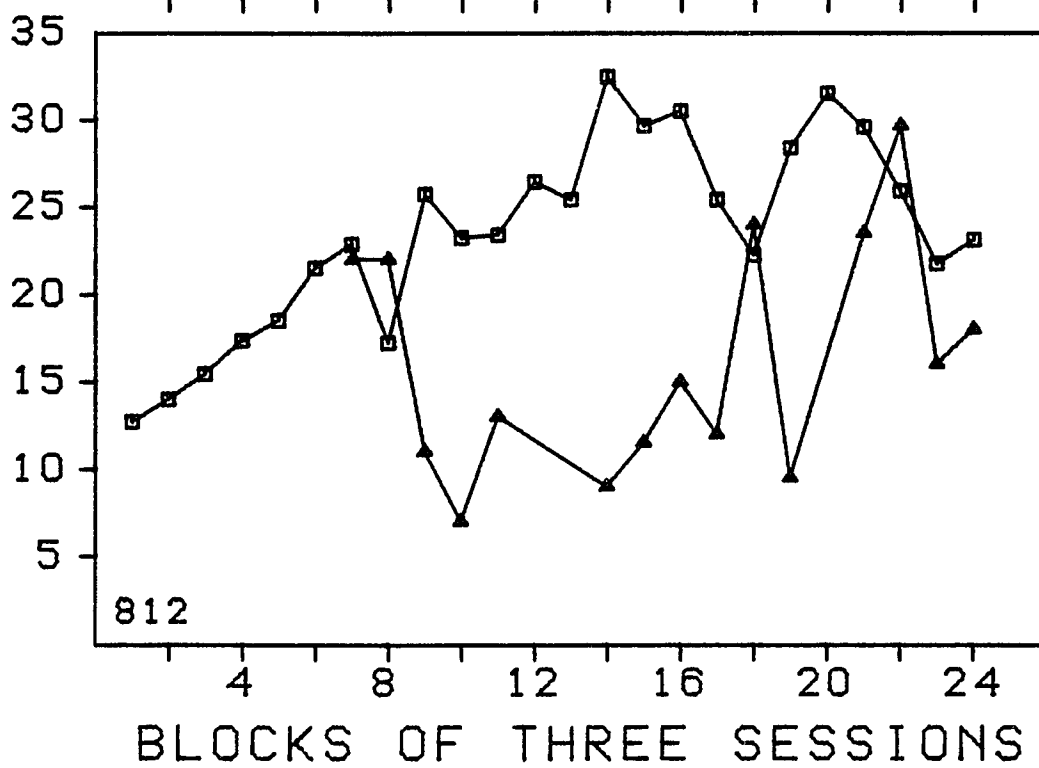
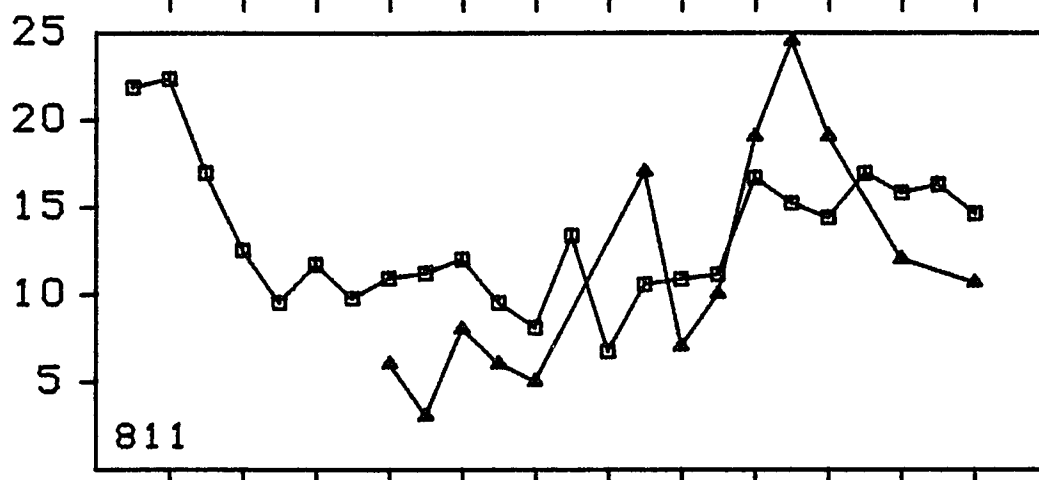
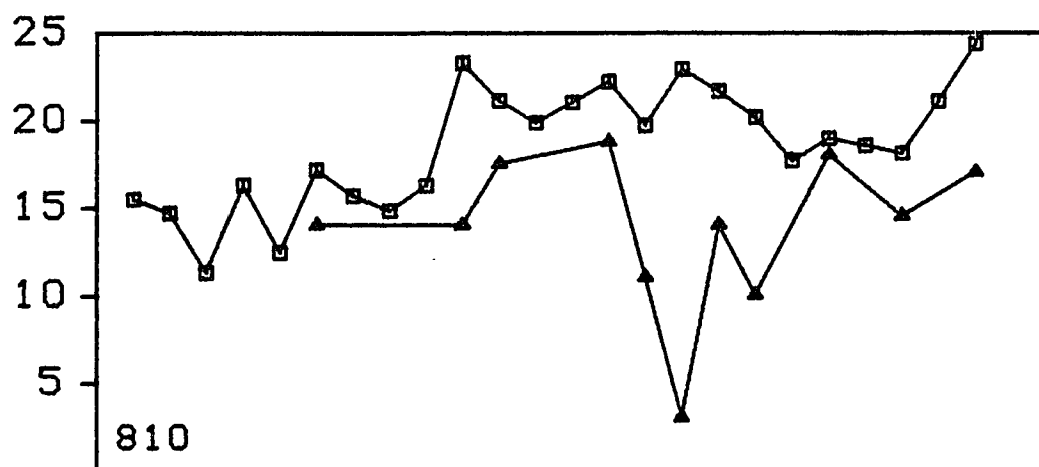


Post-Stimulus Response Counts

Figure 113. Data represent the mean number of lever-presses per component for both post-Sn (squares) and post-Sp (triangles) components. Three-digit numbers identify subjects. Individual data points represent performance averaged over 3 consecutive sessions.

In 2 cases (810 and 812), the lever-press count was consistently lower for post-Sp than for post-Sn components. The same sort of effect is typically observed when comparisons are made between post-food and post-stimulus lever-press counts (compare counts in Figures 2 and 3)-- post-food counts are almost always lower than post-stimulus counts. With respect to lever-press counts, then, the data suggest a similarity between post-Sp and post-food behavior.

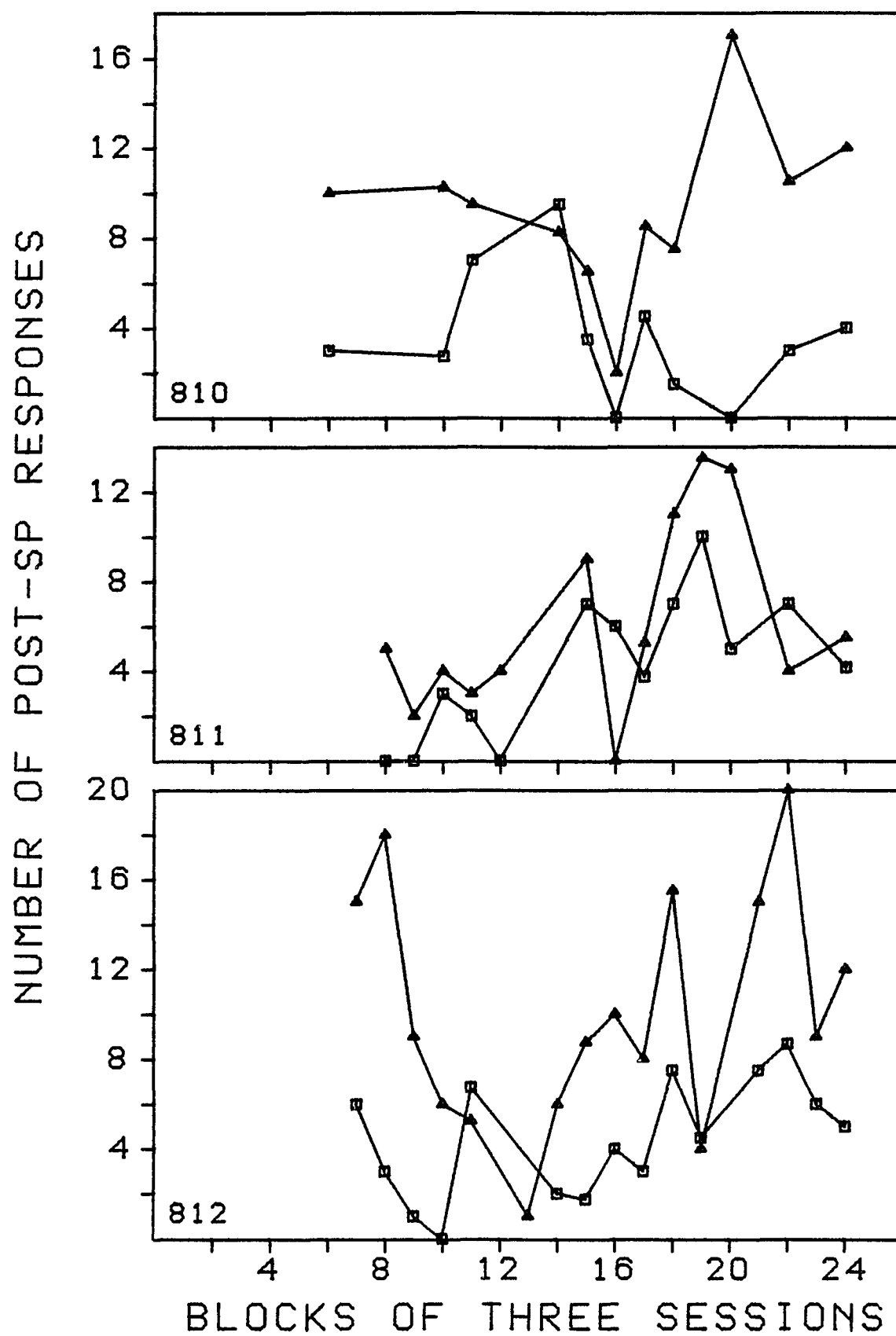
NUMBER OF RESPONSES



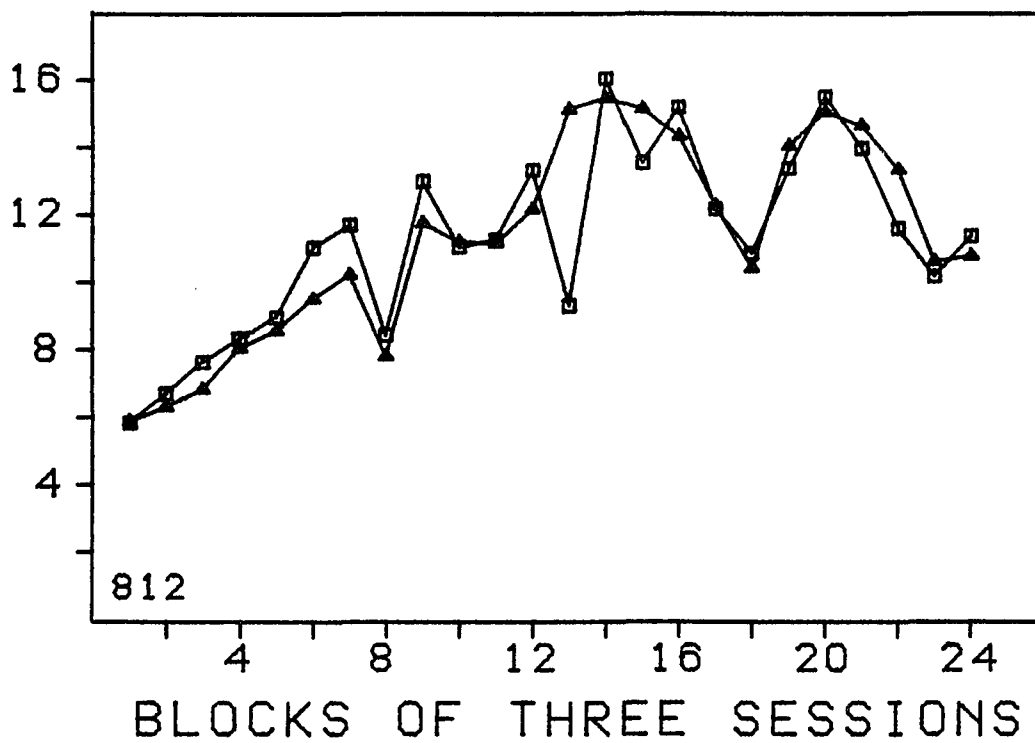
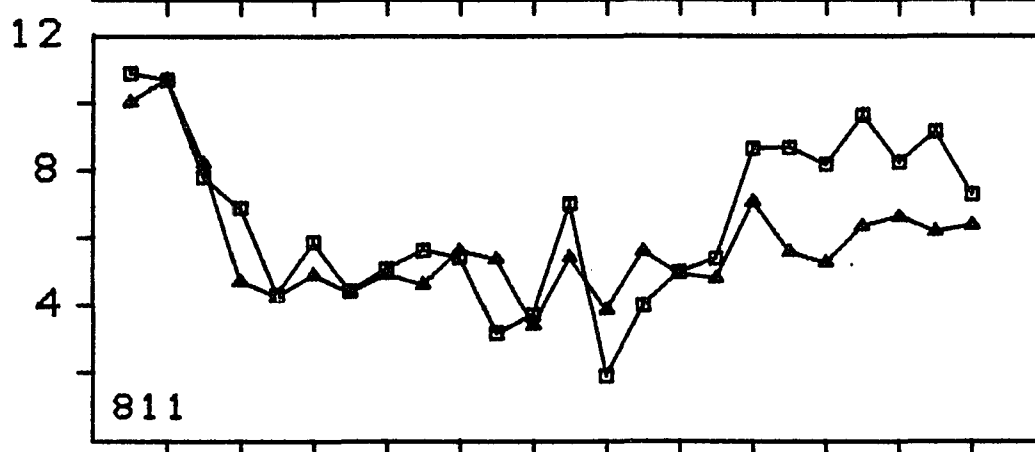
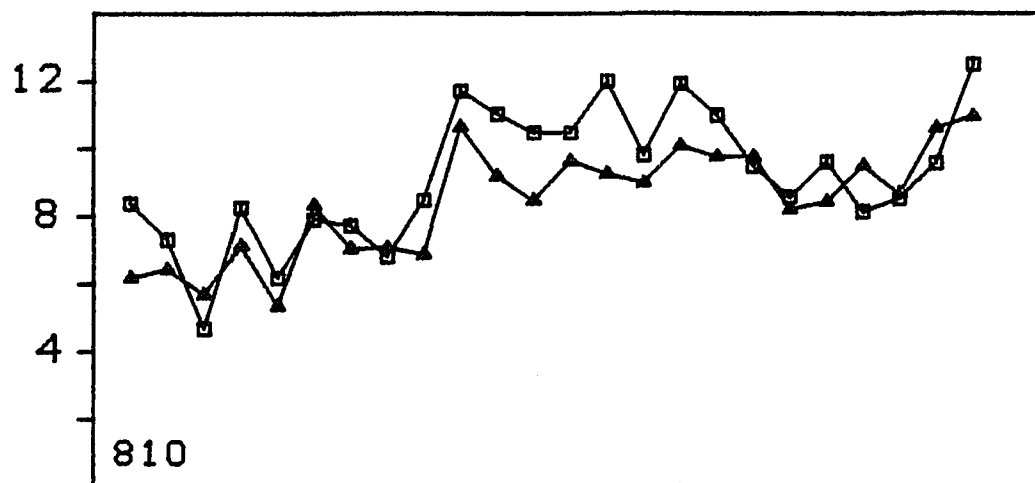
### Post-Stimulus Lever-Press Distributions

Figures 114 and 115. Data represent the mean number of lever-presses per component, broken down according to whether they occurred during the first or the second half (35 sec) of post-stimulus components. Post-Sp distributions are shown in Figure 114, and post-Sn distributions are presented in Figure 115. Within each figure, squares represent behavior during the first half of components, and triangles represent behavior during the second half of components. Individual data points represent performance averaged over 3 consecutive sessions.

For Subjects 810 and 812, lever-pressing typically occurred at a higher rate during the first half than during the second half of post-Sp components, again suggesting a similarity between post-Sp and post-food behavior (Figure 2). The post-Sn distributions, like typical post-stimulus distributions (Figure 3), demonstrate a constant rate of lever-pressing within components.



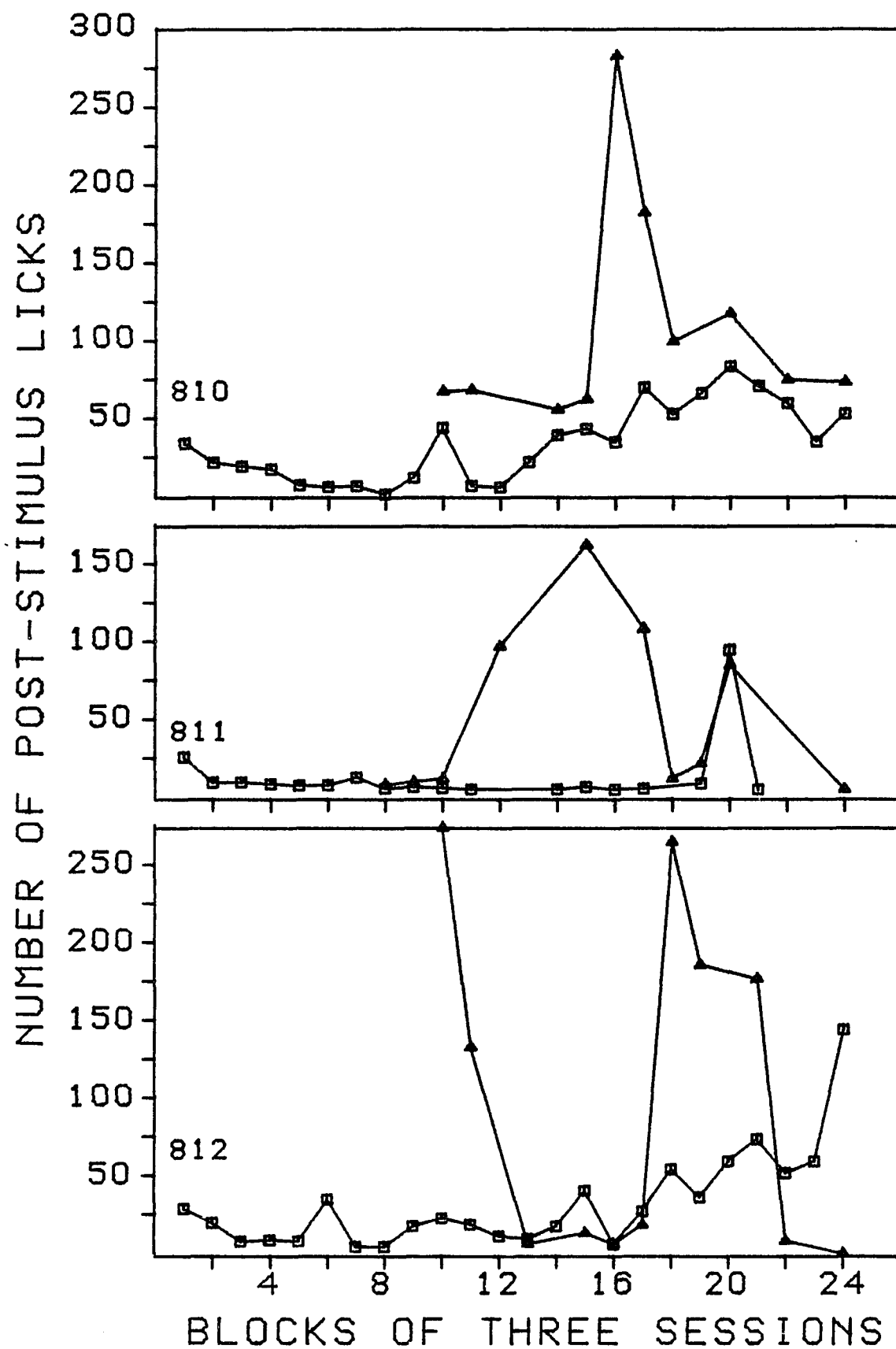
NUMBER OF POST-SN RESPONSES



Post-Stimulus Drinking Levels

Figure 116. Data represent the mean number of licks within both post-Sp (triangles) and post Sn (squares) components during which at least 1 lick bout occurred. Three-digit numbers identify individual subjects. Individual data points represent performance averaged over 3 consecutive sessions.

For all 3 subjects, the number of licks per component was typically greater during post-Sp than during post-Sn components. In several cases, post-Sp levels approximated typical post-food levels (Figure 4); post-Sn levels were always much lower than were typical post-food levels.

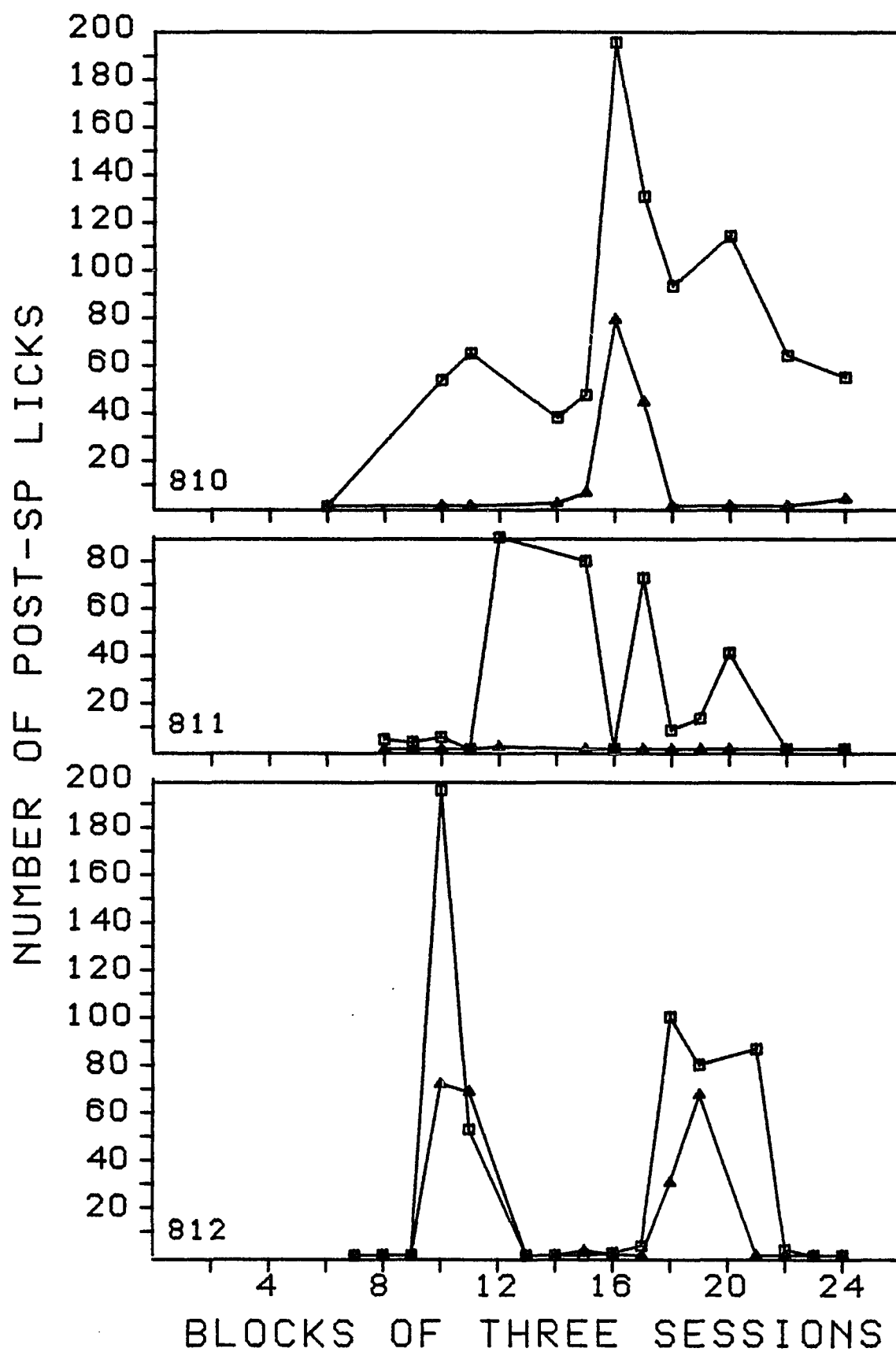




### Post-Stimulus Lick Distributions

Figures 117 and 118. Data represent the mean number of licks per component, broken down according to whether they occurred during the first or the second half (35 sec) of post-stimulus components. Post-Sp distributions are presented in Figure 117; post-Sn distributions, in Figure 118. Individual subjects are identified by 3-digit numbers with plots. Squares represent behavior during the first half of components, while triangles represent behavior during the second half of components. Individual data points represent performance averaged over 3 consecutive sessions.

Post-Sp distributions resemble typical post-food distributions (Figure 5) in that, during most sessions, licking occurred at a higher rate during the first than during the second half of components. The same was true of the post-Sn behavior of Subject 812, but only after extended training. Thus, once again, it is clear that post-Sp behavior typically more closely resembles post-food behavior than does post-Sn behavior.



NUMBER OF POST-SN LICKS

